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Ropes Pyritic Gold Deposit In A Dilational Bend, Marquette Greenstone Belt, Michigan (volumes I And Ii)

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ROPES PYRITIC GOLD DEPOSIT IN A DILATIONAL BEND, MARQUETTE GREENSTONE BELT, MICHIGAN

Volume I

by

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ABSTRACT

The Marquette greenstone belt underlies 300 km^2 of the Upper Peninsula of Michigan. It is 2.7 Ga old, and is considered herein as part of the Wawa subprovince of the Superior province of the Canadian shield, displaced south by Keweenawan age rifting. Rocks are dominantly tholeiitic basalt flows intruded by gabbro and rhyolite sills, with lesser intermediate composition calc - alkalic fragmental volcanic rocks. Major intrabelt intrusions include serpentinitic peridotite in the southwest part, and a composite granodiorite - syenite pluton intruded centrally. Except for amphibolite in the north part, rocks are greenschist facies.

The belt is at least five, and possibly six blocks, each generally with an internally consistent facing direction, sequence of rock types, and metallogeny. Blocks are bound by shear zones, across which correlation of rocks is uncertain or not possible. These shear zones developed in late Archean time, but there was also some component of Early Proterozoic tectonism. Minor gold concentrations in the belt are widespread, and are associated with quartz veins, at brecciated margins of rhyolite intrusions, as zones of dispersed pyrite with gold in basalt or dacite tuff, and with

graphitic, pyritic argillite. The largest and most abundant occurrences are concentrated in two of the blocks, near shear zones which bound the blocks.

The Ropes gold deposit is at the southeast edge of one of the blocks. There are four main rock types in or peripheral to the deposit, but three of these have a peridotite protolith, as indicated by relict textures, or abundances of less mobile elements. A tabular body of quartz - sericite - chlorite rock, interpreted as altered dacite tuff, strikes east northeast and hosts ore. Carbonate - quartz - chlorite rock, interpreted as sheared and altered peridotite, immediately bounds the quartz - sericite - chlorite rock. The carbonate - quartz - chlorite rock is bound on north and south by carbonate - talc rock, then by serpentinitic peridotite.

The Ropes main ore zone is 2.8 million tonnes with 3.7 g/tonne Au. It is near vertical, 335 m in maximum strike, 600 m down - dip, and 12 m in average thickness. Ninety five percent of the ore is dispersed sub 100 micron pyrite with 1 to 10 micron gold included and attached, in the quartz - sericite - chlorite rock. This ore is zoned longitudinally into three subtypes based on differing proportions of quartz, sericite, chlorite and pyrite. Silver is with tetrahedrite, galena and as electrum. Au/Ag is 0.65 overall, very low compared to an average ratio of 4.2 for Precambrian deposits. Five percent of the ore is in layered auriferous quartz veins which contain tetrahedrite.

The deposit is in a dilational bend in a north side down oblique dextral, brittle - ductile shear zone which ranges in attitude from high angle reverse to vertical. Slip was along a line plunging approximately 60° east. Ore is localized in an 080° striking part of the trend of quartz - sericite - chlorite rock, which strikes 070° overall. Contacts between quartz - sericite - chlorite rock and rocks derived from a peridotite protolith were planes of weakness which facilitated shearing. Parts of the major zones of gold concentration characterized by dispersed pyrite within the quartz - sericite - chlorite rock are oriented in right stepping, en echelon, low angle sigmoidal fashion, as are auriferous oblique shear veins at the south side of the deposit. These auriferous zones and veins, along with sericite, chlorite and locally fine grained pyrite follow schistosity and indicate hydrothermal alteration and gold deposition were contemporaneous with shear deformation. The host rock dips less steeply near surface, and narrows updip and along strike, which may have focussed ascending hydrothermal fluids. Carbonatization of serpentinitic peridotite and sericite alteration of dacite tuff, respectively, were sinks for CO_2 and K contained in the fluid. Simple mineral assemblages in rocks and limited ranges of compositions of the major rock forming minerals suggest an advanced degree of homogenization by pervasive fluid flow. East northeast striking carbonate - talc altered trends, mapped or inferred from linear zones of relatively lower total magnetic field within serpentinitic peridotite, may host Ropes - like deposits.

ACKNOWLEDGEMENTS

I sincerely thank those who have helped me with this dissertation. Callahan Mining Corporation of Phoenix, Arizona, through the efforts of Dr. Bruce A. Bouley, provided financial and logistical support, unencumbered access to data, and the opportunity to work as an exploration geologist in the Marquette greenstone belt for most of the past five years. An Ontario Graduate Scholarship also provided financial support. Callahan's exploration management and geologists provided valuable geologic insights: Alan S. Carter and John W. Norby carried out the bulk of the detailed mapping and prospecting in the greenstone belt, and any understanding of many of the gold occurrences and enclosing rocks therein would not be possible without their work. Richard J. Gleason developed and tested initial geologic models for the belt, which were followed up, refined, and extended by Bruce A. Bouley. G. Bradford Margeson managed and participated in exploration and model development as District Geologist over the past three years, with an open minded approach encouraging consideration of all the options. Rodney C. Johnson, through work for Callahan Mining as well as thesis work at

Michigan Technological University, encouraged a consideration of the role of structure in the belt, which his ongoing work will undoubtedly extend. Glenn Scott, chief mine geologist at Ropes, assisted by Jim Bosco and Dennis Bal, were largely responsible for definition and subsurface mapping of fundamental rock types in the Ropes deposit. Dorothy Brozdowski and Judith P. Hegman helped type the manuscript. Silke Schiff compiled whole rock analyses for the Marquette greenstone belt. Joe Papp drafted the isometric diagram of the Ropes deposit. Nelson King, acting Ropes unit manager, provided information on mineralogy of concentrates from the Ropes mill. Professor Robert Hodder was advisor and editor, and provided insights on Precambrian geology of northern Michigan. R. L. Barnett provided guidance in microprobe work. Professors Norman Duke, F. W. Cambray, and Robert Kerrich provided insights, respectively, into regional geology, kinematic indicators and structural fabrics, and crustal-scale structures. Jim Reynolds of Fluid, Inc. provided an overview of fluid inclusion characteristics. My fellow graduate students at U. W. O. shared their enthusiasm, geologic knowledge and exploration expertise.

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CHAPTER 1 INTRODUCTION

1.1 General Statement

This thesis describes the geology of the Ropes gold deposit and its place in the volcanic and structural framework of the Marquette greenstone belt. The genesis of the deposit and the timing of gold concentration are interpreted from macro -, meso -, and microscopic geologic features and geochemical parameters within and peripheral to the deposit. The Ropes gold deposit is presently the only economic concentration of gold in the Marquette greenstone belt, although there are numerous other occurrences both tested and untested, and it affords the best opportunity for describing a gold occurrence and developing exploration models.

1.2 Location and Access

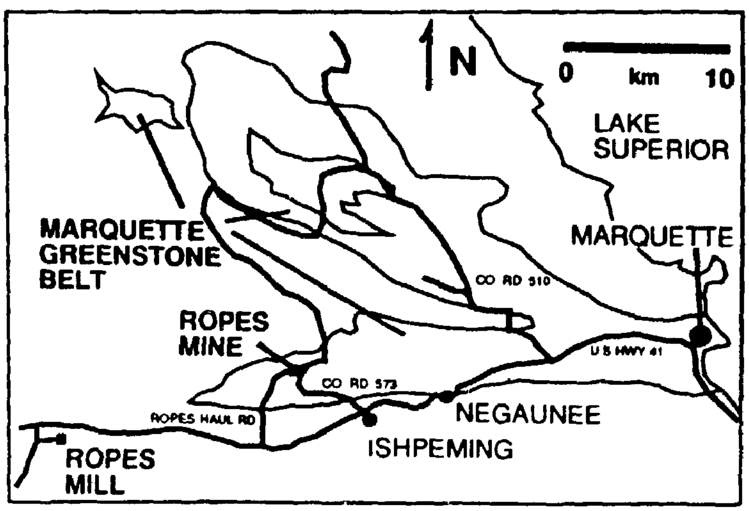
The Ropes gold mine is at 46° 31' north latitude and 87° 43' west longitude, in the S 1/2 NW 1/4 Section 29, T48N, R27W, Ishpeming Township, Marquette County, Michigan, USA. The mine is

5.8 km northwest of the town of Ishpeming, Michigan. Access is north from U.S. highway 41 via paved county road 573 (Deer Lake Road), thence west via unpaved county road GCL (figure 1). The major population center and county seat is the city of Marquette, 16 miles east of the mine. The Marquette county airport, 8 miles east of the mine, has scheduled air service. Most of the population resides in the Marquette - Negaunee - Ishpeming corridor along U. S. highway 41 which traverses the south part of the belt. Access to the northwest part of the belt is moderately good via northwest trending county roads and logging roads, but the far northwest part of the belt is accessible mainly by foot and locally by four wheel drive vehicle.

Regional topographic relief between Lake Superior and the Archean highlands surrounding the Ropes deposit is approximately 300 meters, with local relief up to 100 meters. Outcrop is best near the topographic drop off to Lake Superior in the east part of the Marquette greenstone belt and diminishes to the west. Outcrop ridges are elongate in an east direction, within steep south faces and more gentle north slopes. Glacial drift is widespread but seldom more than 15 meters deep.

Figure 1-1. Location of the Marquette greenstone belt and Ropes gold mine in the Upper Peninsula of Michigan.


ALASKA
CANADA
LOCATION OF STUDY AREA
UNITED STATES


N
0 km 10
LAKE SUPERIOR
MARQUETTE
MARQUETTE GREENSTONE BELT
CO RD 510
ROPES MINE
US HWY 41
CO RD 573
NEGAUNEE
ROPES HAUL RD
ISHPEMING
ROPES MILL

The Marquette greenstone belt is considered herein as an extension of the Wawa subprovince of the Archean Superior province of the Canadian shield (Card and Ciesielski, 1986). Although greenstone belts of the Superior province in Canada host many important gold producing districts, the Ropes mine is the only current producer in the Superior province of the United States. The mine is in the southwest part of the Marquette greenstone belt, which is approximately 300 km^2 of Late Archean volcanic and sedimentary rocks surrounded by Late Archean granite and gneiss to the west and north and by Lower Proterozoic sedimentary rocks to the south and west.

1.3 Scope and Purpose of Thesis

The specific purposes of this thesis are to: (1) describe the geology and metal occurrences of the Marquette greenstone belt as a whole, which up to this time has not been done, (2) describe the geology of the Ropes gold deposit and enclosing rocks, (3) relate deposit - scale geology to the geology of the greenstone belt and region in terms of the position of the deposit within the volcano - stratigraphic and structural framework of the belt, and its setting in the south part of the Archean Superior province, (4) constrain the relative timing of Au concentration in the Ropes deposit, and (5) propose a genetic model to explain the Ropes gold deposit and to advance gold exploration in the area. Recent exploration and development work in and adjacent to the Ropes deposit provided much broader three dimensional geologic relations than was previously available, and the worldwide boom in gold exploration and research during the 1980's provided an extensive base with which to compare and contrast the Ropes gold deposit.

1.4 History of the Ishpeming Gold Range and Discovery of the Ropes Gold Mine

Douglas Houghton, the first state geologist of Michigan, reportedly found coarse gold in a small stream between L'Anse and Marquette, Michigan between 1837 and 1845. Houghton drowned when his canoe capsized and before he could record or follow up his discovery, but according to local legend, the gold came from an area near Ishpeming (Allen, 1912). Gold was reported in vein quartz from the Holyoke silver mine in Section 2, T48N, R27W in January 1864, assayed by Dubois and Williams, analytical chemists of Philadelphia, Pennsylvania. The Holyoke mine was developed by a 160 m adit and a 20 m winze but had no recorded production. In the mid 1860's, galena bearing quartz - carbonate veins were explored by four shallow shafts at the Silver Creek prospect in NE1/4 NE1/4 Section 25, T49N, R28W and by prospecting at the Lead Pits in NE1/4 SE 1/4 Section 34, T49N, R27W.

Julius Ropes, a druggist in Marquette and later Ishpeming, also assayed rock samples for iron and other elements. Woodchoppers brought what they called petrified wood to him, which he found to be asbestos. On one of his exploratory trips for asbestos in the late 1870's he found serpentine with carbonate veins, which he called verde antique marble. Verde antique was subsequently quarried from a small pit west of the future site of the Ropes mine as decorative stone, with the waste crushed for roofing granules. In the fall of 1880, while exploring the serpentinite, Mr. Ropes found a small quartz vein, which he sampled, assayed at home, and found to contain both silver and gold, but not in commercial quantities; however, he continued prospecting because he determined from his books that serpentinites were associated with several gold mines throughout the country. On May .7, 1881, Mr. Ropes discovered a small quartz vein in outcrop which he sampled and assayed at $21 of gold per ton. Soon afterward he discovered the outcrop that led to the development of the Ropes gold mine (Newett, 1921).

Because the land and mineral rights in the area were owned primarily by iron and timber corporations, Ropes' discovery did not create a major gold rush but did touch off a minor prospecting boom in the surrounding hills which became known as the Ishpeming gold range (Parker, 1888; Denning, 1948). Between 1880 and 1890, many shallow shafts and prospect pits were sunk in the area west of the Ropes gold mine (map plate 2). The most significant of these was the Michigan gold mine, in Section 35, T48N, R28W, 4 km west of the Ropes mine, which produced approximately 3175 tonnes of ore at 8.6 g/tonne from quartz veins beginning in August, 1887 (Newett, 1898; 1921). Minor gold prospects south and west of the Ropes mine included the Lake Superior Iron Company, Sanson (or Peninsula), Mockler Brothers, and Case prospects (map plate 2, table 1-1). Julian Case attempted to interest London businessmen in quarrying serpentinite about 1890. In 1910 Daniel Case of Detroit and others organized the Michigan Marble Company to quarry in Section 36, T48N, R28W, but commercial operation never started.

Table 1-1. Au, Ag and base metal concentrations in the Marquette greenstone belt.

Airport prospect--NE1/4 SW1/4 s28 T48N R26W--quartz - carbonate lenses with chalcopyrite, tetrahedrite, pyrite in sheared greenstone--grab sample .64% Cu; trace gold--Resource Exploration, 1975

B&M prospect--SW1/4 NW1/4 s 21 T48N R27W--lenticular quartz vein in graywacke; gold in 0.4 m thick quartz vein in dacite tuff--Kronquist, 1936

Bjork - Lundeen prospect--SW1/4 NW1/4 and NW1/4 SW1/4 s30 T48N R27W--1m to 2 m thick by 400 m long east southeast trending zone of quartz veins in chlorite - pyrite - carbonate rich shear zone, normal to bedding in pillowed basalt--approximately 130,000 tonnes at 3.5 g/tonne Au identified by drilling. Grab samples up to 113 g/tonne from pyrite - tourmaline rich quartz vein selvage--Kelly, 1936a; Calumet and Hecla, 1930s; Norby, 1988a; Brozdowski 1989b

Breitung prospect--NW1/4 NW1/4 s?3 T48N R28W--east striking 0.6 m wide quartz vein in sheared pyritic massive to pillowed basalt with secondary sericite and quartz--trace gold in grab samples--Kelly,1936a

Brown and Case prospects--N1/2 NE1/4 s36 T48N R28W--quartz veins in basalt--trace Au--Kelly, 1936a

Canal prospect--NE1/4 s36 T48N R27W--Lamey, 1935

Carp River Falls prospect--S1/2 S1/2 SE1/4 s29 T48N R26W--300 m long by 10 m wide zone of wavy foliated quartz bearing chlorite - carbonate rock; quartz - sericite phyllite, and fine grained ankerite - quartz lenses--up to 0.6 g/tonne Au in scattered grab samples--Brozdowski, 1987

Coon prospect--NE1/4 NW1/4 s35 T49N R26W--1.5 m quartz vein with gold and base metal sulphides--Lamey, 1935

Craig prospect--SW1/4 s6 T49N R26W--pegmatite dikes in hornblende schist--Zinn, 1936

Fire Center prospects--S1/2 s35 T49N R27W--gold with pyrite at margins of rhyolite sills in basalt--siliceous intervals up to 10 m wide with 0.34 to 2.79 g/tonne Au; 230 tonnes milled 1892 from Beaver shaft and Crescent tunnel with $2063 in Au recovered--Kronquist and others, 1936a; Kelly, 1936a; Carter, 1986.

Giant prospect--SE1/4 NW1/4 s36 T48N R28W--quartz vein in felsite, diorite--Lamey, 1935

Grayling prospect--SW1/4 SE1/4 s26 T48N R28W--0.6 m thick quartz vein with pyrite and carbonate in basalt--up to 2 g/tonne Au in grab sample--Kelly, 1936; Lamey, 1936; Carter, 1988b

Grummet prospect--NE1/4 NW1/4 s36 T48N R28W--carbonate - quartz veins in chlorite schist in basalt--trace Au--Kelly, 1936a

Holiday Inn South prospect--SE1/4 NE1/4 s21 T48N R25W--hematitic, pyritic chert, in upper part of Lower Member of the Mona basalt, up to 10 m thick(?)--grab samples up to 9 g/tonne Au--Brozdowski, 1986a

Holyoke area--SW1/4 NE1/4 s2 T48N R27W--1.) dispersed pyrite in carbonate rich sheared basalt, rhyolite dikes--local grab samples greater than 30 g/tonne Au but no well defined zone; 2) Ag prospect with adit on quartz veins at Holyoke mine, 160 m adit 20 m winze, no recorded production--Kelly, 1936; Carter, 1986.

Hotfoot prospect--SW1/4 SE1/4 s26 T48N R28W--4 m wide shear zone with minor quartz and carbonate veins at north margin of quartz - feldspar porphyritic hypabyssal dacite plug--trace Au in shear zone; up to 13 g/tonne Au in thin siliceous margin of plug--Carter, 1988b

Humble Oil prospect--s6 T48N R26W--cherty iron formation--two drill holes--Resource Exploration, 1975

Kreig prospect--NE1/4 s6 T49N R26W--quartz vein with tourmaline--Lamey, 1935

Lake Superior Iron Mining Co. prospect--NE1/4 NW1/4 s 35 T48N R28W--quartz veins in basalt--Lamey, 1935

Lake Superior prospect--NE1/4 NE1/4 s35 T48N R28W--1 m thick quartz vein with carbonate, chalcopyrite, pyrite; chloritic wall rock; hosted by dacite tuff and basalt--grab samples up to 1.4 g/tonne Au--Kelly,1936a; Carter,1986b

Lead Pits--NE1/4 SE1/4 s34 T49N R27W--quartz veins with galena and sphalerite

Marquette Mall prospect--20 cm thick, tabular, graphitic, pyritic zone parallel to foliation in sericite slate--Au up to 2 g/tonne--Gleason, 1986

McClure Dam prospect--s14 T48N R26W--quartz vein with tourmaline--Lamey, 1935

Michigan mine--NW1/4 NE1/4 s35 T48N R28W--quartz veins in basalt with minor porphyritic rhyolite dikes--locally high grade shoots with Au were focus of mining in 1880's and 1930's, Production was 3175 tonnes at 8.6 g/tonne Au--Wright, 1894; Carter, 1984a

Mockler Bros. prospect--SW1/4 SW1/4 s35 T48N R28--quartz veins in basalt near granodiorite plug--Lamey, 1935

Orianna Brook prospect--SE1/4 NW1/4 s28 T48N R25W--8" thick quartz vein with pyrite quartz - sericite selvages in basalt. Vein strikes 075° along with foliation in enclosing quartz sericite phyllite--sample across vein and selvage up to 6 g/tonne Au--Brozdowski, 1986b

Peninsula prospect--SW1/4 SW1/4 s25 T48N R28W--siliceous pyritic zones with late fracture controlled ferroan dolomite in dacite tuff and in basalt peripheral to small granodiorite plug--

approximately 80,000 tonnes at 4 g/tonne Au identified by drilling--Carter, 1984a 1985c and 1986a

Peppin prospect--SW1/4 SW1/4 s23 T48N R28W--quartz veins in outlier of greenstone in granite--grab samples up to 26 g/tonne Au--Kelly, 1936a

Phillips prospect--SW1/4 NE1/4 s30 T48N R27W--Calumet & Hecla drill hole with 3 m at 2.7 g/tonne--Lamey, 1935

Pickett Lake prospect--SW1/4 NW1/4 s30 T48 N R26W--quartz - carbonate vein with chalcopyrite in basalt--grab samples up to 20.5 g/tonne Au, 2.1% Cu--Kelly, 1936 ; Resource Exploration, 1975

Pine Hill prospect--NE1/4 s26 and NW1/4 s25 T48N R26W--Au in northeast trending structures cutting inter basalt flow dacite tuffs, and graphitic phyllite--up to 9 g/tonne Au with quartz vein, wide carbonate rich zones in basalt anomalous up to 1 g/tonne Au--Brozdowski, 1987

Red Dragon prospect--SE1/4 SW1/4 s31 T48N R27W--quartz vein in basalt--trace Au--Phelps - Dodge, 1986

Ropes mine--S1/2 NW1/4 s29 T48N R27W--Au with dispersed pyrite in quartz - sericite - chlorite rock (dacite tuff) and quartz tetrahedrite veins--total 2.8 million tonnes at 3.7 g/tonne Au--Broderick, 1945; Brozdowski, 1989a

Saux Head prospect--NW1/4 s6 T49N R26W--Lamey, 1935

Silver Creek prospect--NE 1/4 NE 1/4 s25 T49N R 28W-- 1.) Argentiferous galena and sphalerite in shallowly south dipping quartz veins in basalt; 2.) Au with carbonate rich, sheared, brecciated pyritic margins of porphyritic rhyolite branching sill in basalt, 100 m west of the above quartz veins--Norby, 1988b

Silver Creek west prospect--center s23 T49N R28W--Au in east southeast striking shear zone in basalt with ferroan dolomite - sericite - pyrite alteration--Norby, 1988b

Silver Lake prospect--s6 T49N R28W--quartz veins with pyrite, chalcopyrite, in tuff--Kelly, 1936a; Resource Exploration, 1984

Unnamed--SW1/4 SW1/4 s22 T48N R28W--1.5 m thick by 8 m long quartz vein in granite--trace Au--Kelly, 1936a

In June, 1890, Julius Ropes discovered gold in quartz veins northeast of Ropes in the Dead River district, Section 35, T49N, R27W, and organized the Fire Center Mining Company . Shafts were sunk to 30 meters. In 1892, 230 tonnes of ore from the Beaver shaft and Crescent tunnel at the Fire Center area were treated at the Ropes mill, and $2,063 worth of gold recovered. In the fall of 1898, the veins were found to pinch out at depth, and the prospect was abandoned (Allen, 1912). In 1932, on the Yellow Dog plains north of Ropes, glacial drift was bulk sampled and drilled for placer gold, but no commercial operation resulted.

In 1934, Calumet and Hecla acquired the Ropes mine and adjacent leases to the west and did extensive drilling, trenching, and prospecting in the area until 1942, including 3 holes east of Ropes totalling 390 m, 8 holes west of Ropes totalling 1252 m, and 5 holes at the Bjork - Lundeen prospect 1.7 km west of Ropes totalling 643 m. In 1934, the Marquette Mining Company dewatered the Michigan mine and milled 500 tonnes, but there is no record of gold produced. The Norgan Gold Mining Company conducted work in the Marquette greenstone belt around 1936, and also trenched and drilled 13 holes totalling 610 m at the Fire Center mine. War time restrictions on gold mining resulted in termination of all gold exploration in 1942.

From the 1960's through 1980 there was periodic exploration throughout the belt for base metal massive sulfide deposits without success. Cleveland Cliffs Iron Company drilled 3 holes at the Michigan mine in 1966. Humble Oil Company explored the middle and southwest parts of the Marquette greenstone belt for base metals from 1968 to 1971 and locally analyzed for gold and silver. They drilled 2 holes into iron formation, and 2 holes to test a conductor in a topographic low, totalling 610 m. During the 1970's, a Bethlehem Steel - Cleveland Cliffs Iron Company joint venture explored the belt for base metal sulfide deposits. A Superior Oil Company - Nicor Mineral joint venture prospected the middle and northwest parts of the belt for massive sulfide deposits from 1972 to 1985 and drilled several geophysical and geochemical anomalies through 1982, but changed their emphasis to gold in 1982, drilling 14 holes totalling 1433 m in the Holyoke mine area, Section 2, T48N, R27W. The NOMEX joint venture, formed by Chevron and Cleveland Cliffs Iron Company, explored the southwest part of the belt and drilled 4 holes totalling 832 m at the Bjork - Lundeen prospect and 4 additional holes totalling 512 m west of the Ropes deposit. Callahan Mining Corporation conducted regional surveys for base metals and later gold in the belt, beginning in the mid 1970's and continuing through the present. St. Joe American Corporation prospected a patchwork of land in the belt about 1983 but did no drilling. Kerr - McGee Corporation prospected the south half of the north part of the belt for gold from 1984 to 1988, and did some drilling. Phelps - Dodge Corporation prospected the southwest part of the belt from 1985 to 1986 and drilled one 250 m hole east of the Ropes deposit.

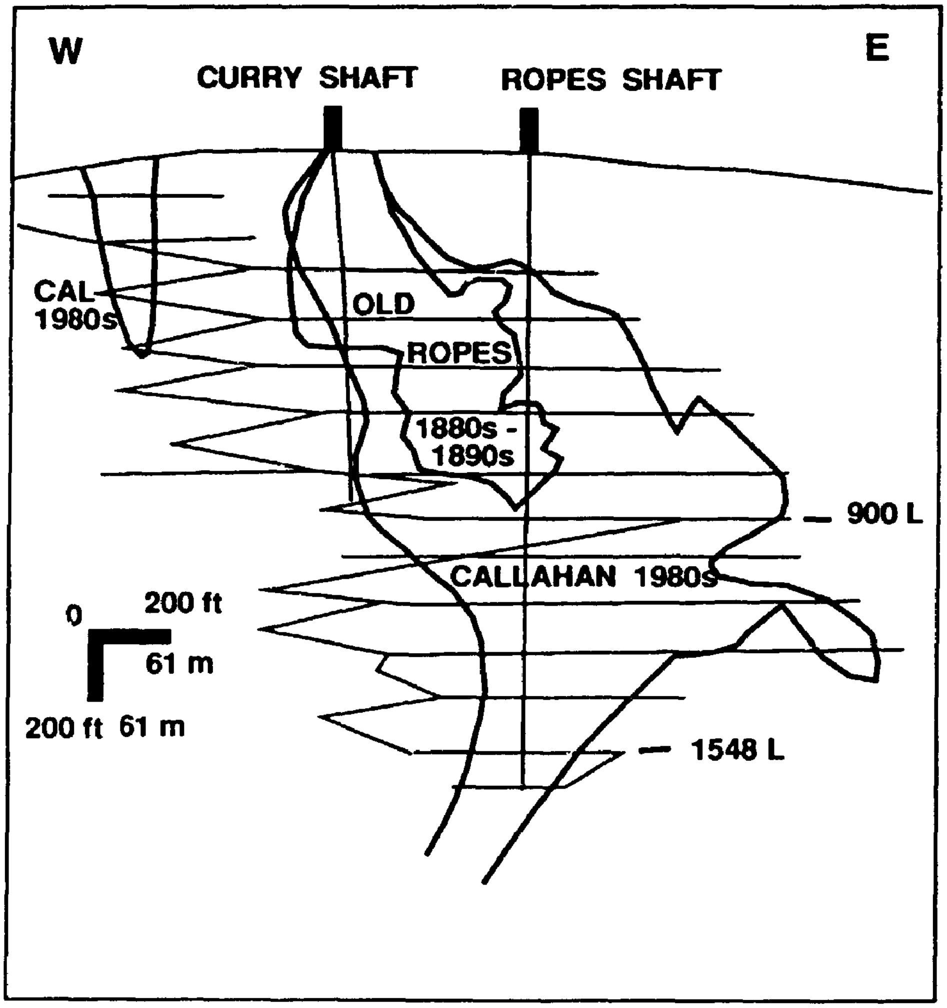
1.5 Development of the Ropes Gold Mine

The Ropes Gold and Silver Company was formed August 20, 1881, when Julius Ropes, in partnership with Dr. Carpenter, S.S. Curry, and G. P. Cummings, purchased the land where he had discovered gold (Clem, 1961). Several shafts were started, but they decided that one would be adequate, and it was named the Curry shaft in honor of S. S. Curry, an experienced miner and a company director. A 5 stamp mill built by Frazer and Chalmers, Chicago, was started on August 7, 1883 and increased to 25 stamps shortly thereafter.

Production increased steadily from 1882 to a peak in 1889 with $57,684.75 of gold and silver produced in that year. In 1890, a new mill with forty 850 pound stamps was built by George Mannie of Ishpeming, and the old mill was decommissioned. The new mill had difficulty treating ore from deeper levels of the mine, because of its talc content. Experimentation to improve recovery was not successful, a tax assessment was not paid, and the mine and mill closed in July 1897. Ore production was 195,000 tonnes between 1882 and closure yielding 1,029 kg of gold, and 2,057 kg of silver (Annual Report of the Commissioner of Mineral Statistics of the State of Michigan, various years from 1880 - 1898; Broderick, 1945). Ore was developed by following quartz veins and siliceous zones. This was crushed by stamp mills and spread over frue vanners to recover coarse free gold. Overflow from the vanners was amalgamated with mercury to recover fine gold. Gold was separated from the mercury in a retort. The mine was developed to a depth of 250 meters below surface on 15 levels (figure1-2).

The property was sold at public auction to Corrigan McKinney and Company in 1899. The new owners cyanided approximately 27,200 tonnes of tailings and processed amalgam found on old mill

Figure 1-2. Vertical long section in the 080° plane, illustrating history of development of the Ropes mine.



DEVELOPMENT OF ROPES GOLD MINE
Long Section (Looking N 10°W)

plates to recover $54,682.38 in bullion in 1900 and 1901 (Barrett, 1926; Broderick, 1945). The mine remained inactive until 1933, when local businessmen organized the Ishpeming Gold Mining Company. Calumet and Hecla Consolidated Copper Company acquired title to the property in 1934 and conducted extensive surface and underground exploration from 1935 to 1937, including 777 m of underground development, 94 underground drill holes totalling 3318 m, and 6 surface drill holes totalling 782 m, outlining an additional 1,393,000 tonnes of gold ore with disseminated pyrite averaging 3.98 g/tonne Au (Broderick, 1936). The grade, subeconomic at that time, and War Powers Act restrictions on precious metal mining imposed in 1942 ended this phase of interest in the mine (Broderick, 1945). Arcadian Copper Mine Tours acquired the property in 1955, but insurance and mine rehabilitation problems rendered the idea of operating it as a tourist attraction unfeasible.

W. H. Bodwell of Resource Exploration Inc., at that time the mineral exploration arm of Longyear Realty Corporation, obtained the Calumet and Hecla data package from Arcadian Copper Mine Tours in 1973 upon recognizing the possible economic potential of the Ropes property through his study of Upper Peninsula non ferrous metal potential (Bodwell 1972, 1974). Around 1974, Exxon Minerals' major discovery at Crandon, Wisconsin created exploration interest which spilled over into Michigan. In 1974, Superior Oil and Minerals financed evaluation of the Calumet and Hecla data on the Ropes mine by Resource Exploration, Inc., resulting in a total reserve estimate of 2.45 million tonnes at 3.32 g/tonne Au, composed of 1.18 million tonnes indicated at 3.97 g/tonne Au and 1.27 million tonnes inferred grading 2.77 g/tonne Au. Ben F. Dickerson III, then exploration manager of Superior's mineral division, rejected the property as being too small but mentioned the property to Fredrick M. Beck, Callahan Mining Corporation's exploration manager. In 1975, Callahan purchased the 80 acre property fee title for $60,000 cash and a retained 3% net smelter royalty. Resource Exploration received a finder's fee of $.05/ton of ore extracted as an overriding production royalty.

In 1979, King Troensgaard and Grant Tonkin carried out a surface exploration program for Callahan Mining Corporation through Resource Exploration, Inc., including geologic mapping, collection of soil samples, 7600 line meters of magnetic, electromagnetic, and induced potential surveys and two drill holes totalling 244 m to test an IP anomaly. From 1980 to 1981 Longyear drilled surface drill holes totalling 3487 m to confirm Calumet and Hecla's reserve figures and geologic interpretation. Most of the inclined holes reached vertical depths of 60 to 365 m on the Ropes main ore zone immediately east of the old workings. Several drill holes indicated that gold concentrations continued deeper than the old 15th level (Resource Exploration, 1980a, 1980b). In April, 1981 the mine was completely dewatered, the Curry shaft and the old 9th and 15th levels rehabilitated and 2438 m of core drilling and bulk sampling completed. Metallurgical test work was done and a flow sheet was developed by the Michigan Technological Institute of Mineral Research. In 1983, a spiral 4.3 m by 4.6 m decline was driven at 12% grade to access the orebody.

A final decision to fund development of the mine, based on underground drifting and drilling, was made in June 1984. Callahan acquired and renovated the Humboldt iron ore flotation mill in Champion, Michigan, for processing gold ore. Production began in September, 1985 (Callahan Mining Corporation Annual Reports, 1982 to 1988). The deposit is mined by a modified blasthole stoping method on levels approximately 34 m apart vertically, at a rate of

1800 tonnes per day. Ore is hauled to surface via a 10 tonne skip up a production shaft commissioned in 1986. A limited amount of ore as well as most development rock is hauled up the decline, which is also used for equipment and personnel access (figure 1-2).

1.6 Metal Inventory

Total production from Callahan Mining Corporation's operation of the Ropes mine though December 31, 1988 has been 4,710 Kg Au and 5,816 Kg Ag from 1.95 million tonnes of ore (Callahan Mining Corporation Annual Reports, 1985 to 1988). Total tonnage of ore zones, including historic production and present geologic reserves is 2.8 million tonnes at 3.71 g/tonne Au.

1.7 Previous Work

The earliest references to the geology of the Ropes gold mine are in reports to stockholders of the Ropes Gold and Silver Company (1885 to1894) in which Julius Ropes listed the ore minerals and noted the volcanic nature of the rock containing the ore zones (Ropes, 1890). Newett (1921) wrote a brief history of the Ropes

Table 1-2. Ropes mine ore tonnage and total gold inventory

	tonnes	Kg Au (recovered)	Au g/tonne (recovered)
Original Ropes Mine 1882-1897	195,000	1029.60	5.28
Cyanidation of tailings	27,215*	68.04+	2.50
		Kg Au (contained)	**Au g/tonne (contained)**
Ropes main and northwest ore zones, total geologic reserves (includes ore already milled by Callahan Mining Corp)^	2,556,485	9203.35	3.6
Total Au inventory	2,778,700	10,300.99	3.71

* not included in total mined tonnage, reworking of original Ropes mine tailings

\+ estimated 80% of dollar value assumed to be Au

^ does not include deep east Ropes Au concentration, which is separate from Ropes main ore zone mine and the Ishpeming gold range. Broderick (1945) briefly described the geology of the Ropes mine, based on his work with Calumet and Hecla Consclidated Copper Company, and reported on history, types of alteration, types of ore, and ore minerals. Rossell (1983) described the Deer Lake Peridotite, the serpentinite adjacent to the Ropes mine, and modeled element fluxes during alteration. He interpreted protoliths of the Deer Lake Peridotite as harzburgite and lherzolite. Shepeck (1985) focussed primarily on the minerals and variance of element abundance in whole rocks in parts of the ore and veins at the Ropes deposit, and to a lesser extent on chemical composition of micas and chlorite, and fluid inclusion and stable isotope abundances in several quartz veins. Creasy (1981, 1982) described rocks from the Ropes deposit which he interpreted as fine grained volcanic, tuffaceous and chemical sedimentary rocks.

The geology of the south part of the Marquette greenstone belt was mapped at 1:24,000 scale by Gair and Thaden (1968), Puffett (1974), Cannon and Klasner,1975; 1977), and Clark and others (1975). The latter workers mapped the Negaunee southwest quadrangle, which contains the Ropes gold deposit. Hagni (1954) described rocks of the Kitchi Schist south and east of the Ropes gold mine as volcanic conglomerates. Parts of the north arm of the greenstone belt were mapped at 1:6000 scale by Owens and Bornhorst (1985), Johnson and others (1986), MacLellan and Bornhorst (1988) and Small and Bornhorst (1989). Engel (1954) mapped and described the metasediments of the Holyoke mine area, presently known as the Reany Creek Formation (Puffett, 1969). Van Schmus (1974), Hammond (1976), Van Schmus (1978), and Hammond and Van Schmus (1978) provided a limited number of age determinations on Archean rocks of the Marquette greenstone belt and adjacent Northern complex.

Morey and others (1982) compiled the geology of the Lake Superior Region, including the central Upper Peninsula of Michigan, and Morey (1978) described metamorphism in the U. S. Lake Superior region in the context of crustal evolution. Case and Gair (1965) compiled a magnetic map of the western Upper Peninsula of Michigan, and Klasner and others (1979b) compiled a Bouguer gravity anomaly map of the Lake Superior region in northern Michigan. Sims (1976a, b, 1987) and Sims and others (1987) reviewed mineral deposits and tectonics of the Lake Superior region. Bodwell (1972) compiled nonferrous metal occurrences in the Precambrian rocks of northern Michigan, and Gleason (1985) compiled additional precious and base metal occurrences in the Marquette greenstone belt. Van Hise and Bayley (1897) and Van Hise and Leith (1911) provided the first regional geologic compilations and maps of the southern Lake Superior region. Klasner and others (1982) reviewed the pre - Keweenawan tectonic history of the southern Canadian shield. Morey and Sims (1976) and Sims and others (1980) described the Great Lakes tectonic zone separating Late Archean Superior province granite - greenstone terrane from older Archean Southern complex gneiss terrane. Sims and others (1981) described the evolution of Early Proterozoic basins of the Great Lakes region. Klasner (1978) described Penokean deformation and metamorphism associated with the Early Proterozoic Penokean orogeny in the Marquette Range Supergroup, and Cannon (1973) reviewed the Penokean orogeny in northern Michigan.

1.8 Methodology

This thesis is based on 4 years of field work as an exploration geologist in Callahan Mining Corporation's Marquette district. Approximately one half of thr author's time was spent on exploration oriented geologic mapping and compilation work, utilizing surface, drill core, and underground development data, in and peripheral to the Ropes gold deposit, with the remainder of the time devoted to reconnaissance exploration and property evaluation of other areas within and surrounding the Marquette greenstone belt. Additionally, 1.5 years were spent at the University of Western Ontario where petrography, electron microprobe mineral analyses, scanning electron microscopy, data processing, and background research were completed.

Over 65 square km of geologic mapping by Callahan Mining Corporation's exploration department, and 24 square km of geologic mapping by Michigan Technological University Master's Thesis students, all at 1:6000 or larger, was available to the author. The data base for the Ropes deposit includes 27,000 m of core drilled from surface, 18,000 m of core drilled from underground, 4,000 m of decline exposure, and 3,200 m of development drifts. The author logged 11,000 m of the above core, and reviewed and collected samples from many other drill holes and underground workings. Isometric diagrams of the Ropes deposit, compiled by Glenn Scott, chief mine geologist, were instrumental in depicting three dimensional geologic relations. Approximately 380 thin sections prepared prior to this study along with 200 new thin sections and 100 polished sections from samples collected by the author from the Ropes deposit were used along with 200 thin sections from other parts of the Marquette greenstone belt.

Analytical procedures and supporting information for major, trace, and rare earth element analyses of whole rocks; correlation matrices; principal components factor analysis; analyses of minerals by electron microprobe; petrographic examination of flotation mill concentrate; metal distribution and gold/silver; carbon and oxygen isotopic analyses of carbonate minerals; determination of fluid inclusion characteristics; age determination by K/Ar of sericite; and carbonate and alkali saturation indices are included in Appendix A.

This thesis presents a revised and more complete review of the geology of the Ropes deposit, with greater emphasis on the role of structure, than was presented in a previous paper for which this author was senior author (Brozdowski and others, 1986).

CHAPTER 2 REGIONAL GEOLOGY

2.1 General Statement

The Precambrian of the central Upper Peninsula of Michigan (table 2-1, figure 2-1) includes: 2.6 to 3.8 Ga Archean gneiss terrane of the Southern complex; 2.6 to 2.7 Ga Late Archean granite - greenstone terrane of the Superior province of the Canadian shield, locally known as the Northern complex; 1.9 to 2.1 Ga Lower Proterozoic sedimentary rocks of the Marquette Supergroup, with 1.83 to 1.89 Ga volcanic and plutonic rocks of the Wisconsin magmatic terrane; and 1.0 to 1.2 Ga Middle Proterozoic volcanic and sedimentary rocks of the Keweenawan Rift system (Sims and others, 1987). The central Upper Peninsula is crossed by several major crustal structures including the nearly east striking Great Lakes tectonic zone (Sims, 1980), which projects through the Marquette trough, and the north northeast striking Trans Superior tectonic zone which passes through the west part of the Northern complex (Klasner and others, 1982).

Table 2-1. Geologic column for the Marquette area, Upper Peninsula of Michigan (Modified from Boyum, 1975).

Cenozoic	Pleistocene		-Glacial deposits
Paleozoic	Ordovician-Cambrian		-Limestone and sandstone
Proterozoic	(Middle Proterozoic) Keweenawan		-Jacobsville sandstone -Diabase dikes -Yellow Dog and Presque Isle (?) peridotites
	(Lower Proterozoic)		-Humboldt granite: alkali feldspar granite, 1.75 Ga -Diabase dikes
	Marquette Range Supergroup	Baraga Group	-Michigamme Fm., includes black slate, graywacke, iron fms.; equivalent to basaltic and felsic volcanic rocks of Hemlock and Clarksburg volcanics -Goodrich Fm.: quartzite, graywacke, and conglomerate
		Menominee Group	-Negaunee Iron Fm. -Siamo Slate -Ajibik Quartzite
		Chocolay Group	-Wewe Slate -Kona Fm.: dolomite, argillite, and quartzite -Mesnard Quartzite -Enchantment Lake Fm.: conglomerate, granitic regolith, and slate
			-Tilden granite: 2.35 Ga
Archean (?)			-Reany Creek Fm.: conglomerate, slate , graywacke, and arkose -Palmer Gneiss: possibly includes Archean volcanic rocks
Archean	(Late Archean)	Marquette Greenstone belt and associated intrusions (approx. 2.6-2.7 Ga)	-Dead River Pluton: granodiorite and syenite -Deer Lake Peridotite -Rhyolite sills -Slate and graywacke with volcanic provenance -Dacite tuff, tuff breccia, and volcanic conglomerate -Basalt: pillowed and massive, with gabbro sills; parts are at amphibolite facies
			-Northern complex (Compeau Creek) tonalite gneiss, with subordinate more massive granitoid rocks
	(older Archean) approx. 2.8-3.2 Ga		-Southern complex gneiss: foliated tonalite gneiss, coarse grained microcline microperthite gneiss, porphyritic adamellite gneiss, subordinate granodiorite, minor amphibolite

Figure 2-1. Geologic map of northern Michigan, Wisconsin and Minnesota.

(simplified from a compilation by Callahan Mining Corporation, from numerous U. S. Geological Survey; Ontario Geological Survey; and Michigan, Wisconsin and Minnesota state geological survey sources).

11. Phanerozoic sedimentary rocks (0.40 - 0.57 Ga)

10. Keweenawan sedimentary rocks (1.0 Ga)

9. Keweenawan basalt flows (1.10 - 1.12 Ga)

8. Keweenawan Duluth complex (1.1 Ga)

7. Baraboo Quartzite and correlatives (1.5 - 1.8 Ga, mostly 1.76 Ga)

6. Wolf River batholith (1.47 - 1.50 Ga)

5g. Wisconsin magmatic terrane: granite (1.835 Ga)

5gn. Wisconsin magmatic terrane; gneiss (1.835 - 1.865 Ga)

5c. Wisconsin magmatic terrane: Chippewa - Wausau belt volcanic rocks (1.83 - 1.89 Ga)

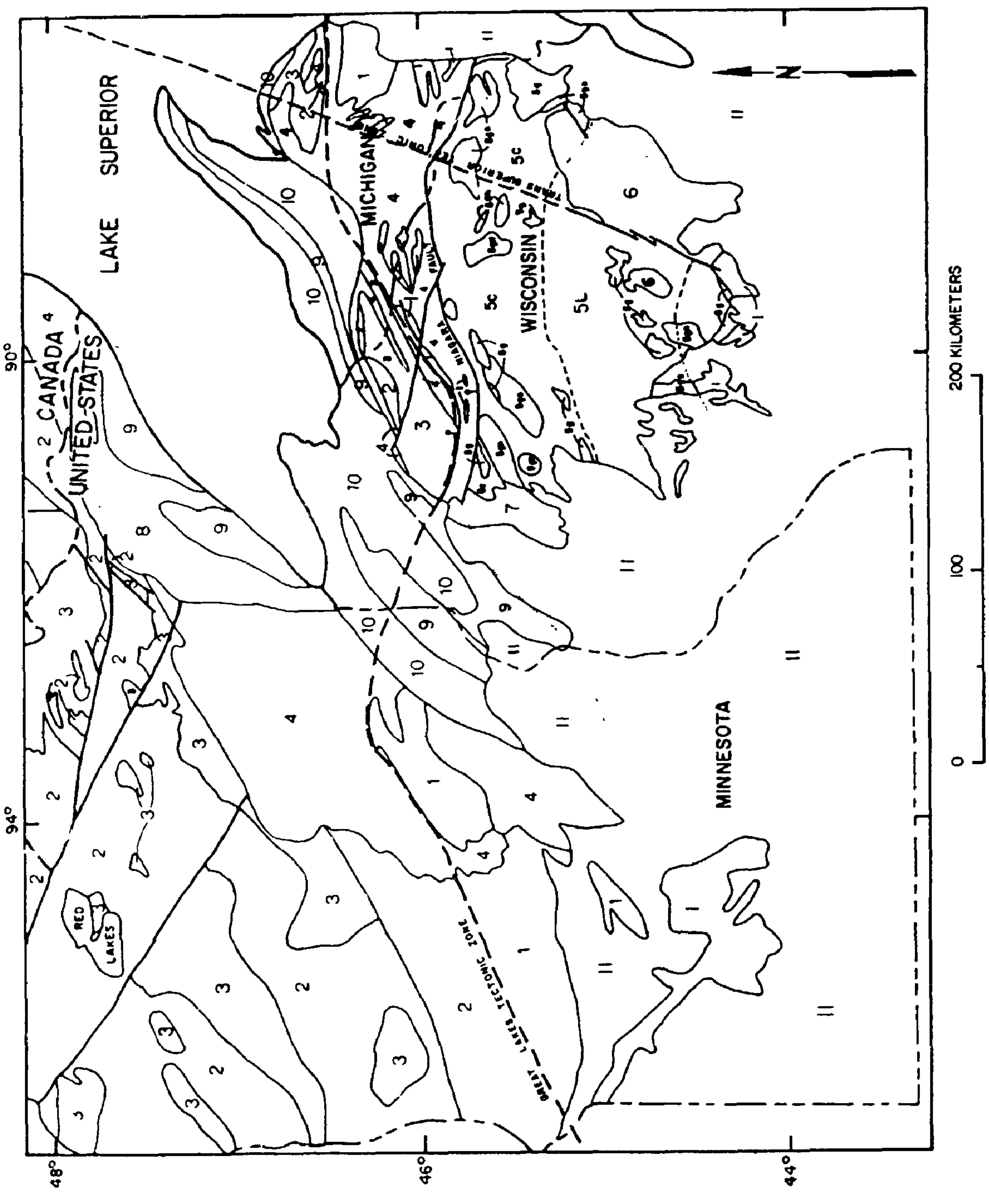
5l. Wisconsin magmatic terrane: Ladysmith - Pembine belt volcanic rocks (1.83 - 1.865 Ga)

4. Lower Proterozoic sedimentary rocks (1.85 -2.1 Ga)

3. Late Archean Superior province tonalite gneiss and granite (2.65 - 2.7 Ga)

2. Late Archean Superior province greenstone belts (2.7 Ga)

1. Early to Late Archean Southern complex gneiss (2.6 - 3.8 Ga)



LAKE SUPERIOR
CANADA
UNITED STATES
MICHIGAN
WISCONSIN
MINNESOTA
RED LAKES
GREAT LAKES TECTONIC ZONE
90°
94°
48°
46°
44°
0
100
200 KILOMETERS
N

The Precambrian of northern Michigan is a major past and present metal producer (Sims, 1984), most prominently iron from the iron formations of the Marquette Supergroup, where over 1.15 billion tonnes of ore were shipped from the Marquette, Menominee, and Gogebic iron ranges between 1846 and 1988 (Boyum, 1975; 1988; and Burton Boyum, personal communication, 1989), and copper from amygdaloidal basalts (White, 1968) and Nonesuch Shale (Ensign and others, 1968) of the Keweenawan rift system. A large, low grade Cu resource of greater than 300 million tonnes of 0.5% Cu as chalcopyrite - bornite - chalcocite is in the Lower Quartzite Member of the Lower Proterozoic Kona Dolomite south of Marquette (Taylor, 1972; Morgan, 1975; and Brown, 1986b). There has been only modest gold production from the Superior province in the United States, mostly from the Ropes gold mine in Ishpeming, Michigan (Broderick, 1945; Rossell, 1983; Shepeck, 1985; Bornhorst and others, 1986; Brozdowski, 1988), in contrast with 4.5 million Kg of Au mined from the Superior province in Canada (Franklin and Thorpe, 1982, Colvine and others, 1988).

2.2 Precambrian of the Central Upper Peninsula of Michigan

2.2.1 Archean Gneiss Terrane; Southern Complex

The oldest rocks in the region are tonalite and adamellite gneisses of the Southern complex (table 2-2) part of a 2.6 to 3.8 Ga gneiss terrane exposed in the Minnesota River valley of southwest and east central Minnesota, northern Wisconsin, and northern Michigan (figure 2-1) (Sims and others, 1987). The gneiss is in cores of domes and uplifted fault blocks that formed by reactivation of basement during and after Early Proterozoic Penokean deformation (Morey and others, 1982). The original extent of this gneiss terrane is uncertain; it may have been part of a proto - continent of substantial size, composed of volcanic and associated intrusive rocks (Sims and others, 1984) that was metamorphosed to granulite and amphibolite facies at moderately deep crustal levels (Sims, 1984).

South of Marquette the main local mass of the Southern complex (VanHise and Bayley, 1895) outcrops sporadically over an area of 1240 km^2 and has two major rock types (Cannon and

Table 2-2. Compilation of Radiometric ages of rocks, southern Lake Superior region (Details for each sample are listed on following pages of this table according to the number in first column).

Locality/ Rock Type	Radiometric Age	Method(s)	Reference(s)
Superior Province			
1.	2700+/-15 my	U-Pb zircon	Van Schmus (1978)
2.	2700+/-15 my	U-Pb zircon	Van Schmus (1978)
3.	2600+/-15 my	U-Pb zircon	Van Schmus (1978)
4.	2700+/-15 my	U-Pb zircon	Hammond (1976)
5.	2700+/-15 my	U-Pb zircon	Hammond (1976)
6.	2700+/-15 my	U-Pb zircon	Hammond (1976)
7.	2650+/-50 my	U-Pb zircon	Van Schmus (1974)
8.	2750-2700 my	various methods (summary)	Goldich (1972)

Southern Province

9.	3500-3800 my	Rb-Sr and U-Pb zircon	Goldich and Stern (1970) Goldich and Hedge (1974)
10.	3680+/-70 my	Rb-Sr whole rock	Goldich and others (1980)
11.	3000-3500 my	U-Pb zircon	Peterman and others(1976)
12.	3535+/-45 my	U-Pb zircon (by ion microprobe)	Williams and others(1984)
13.	3043+/-26 my	U-Pb zircon (by ion microprobe)	Williams and others (1984)
14.	3560 my (approximate)	interpretation of primary ages: Rb-Sr whole rock and mineral systems were reset	Peterman and others (1985)
15.	2750-2800 my	U-Pb zircon	Hammond (1976)
16.	2500-2800 my	Rb-Sr whole rock	Van Schmus and Woolsey (1975)

Southern Complex, Intrusions and Reset Ages

17.	2345+/-20 my	U-Pb zircon (apparent age)	Hammond (1976)

18.	2545+/-7 my	U-Pb zircon (remnant zircon that survived melting of crustal parent?)	Hammond (1976)
19.	2640 my	U-Pb zircon	Peterman and others (1986)
20.	1626+ -20 my (younger mineral ages reflect internal re-equilibration of Rb-Sr system during metamorphism)	Rb-Sr biotite isochron	Van Schmus and Woolsey (1975)
21.	1661+/-79 my	Rb-Sr whole rock isochron	A.Turek,personal communication in Peterman and others (1985)

Marquette Supergroup

22.	1985 my	U-Pb zircon	Banks and Van Schmus(1971)

Superior Province

1. Compeau Creek Gneiss, gneissic tonalite, drill hole DL-4B, Northern Complex

2. porphyritic rhyolite tuff, drill hole DL-5, Northern complex, probable extension of Marquette greenstone belt under Clark Creek basin

3. microcline rich granite, drill hole DL-7, Northern complex, Compeau Creek Gneiss, off NW cor. Marquette greenstone belt

4. Compeau Creek Tonalitic Gneiss, Northern complex

5. granodiorite, Northern complex

6. quartz porphyry, Silver Creek prospect intrusion, Northern complex, Marquette greenstone belt

7. quartz - feldspar porphyry, Silver Creek prospect intrusion, Northern complex, Marquette greenstone belt

8. northern Minnesota Superior province volcanic and plutonic rocks

Southern Complex

9. Minnesota River Valley Gneisses

10. granodioritic gneiss, central Minnesota River Valley

11. Southern complex gneiss, southern Marquette County

12. tonalitic gneiss, southern Minnesota River Valley

13. deformed granite, southern Minnesota River Valley

14. Watersmeet Gneiss Dome, northern Michigan

15. dark gray banded gneiss, Southern complex gneiss, south of Tilden Mine, Ishpeming, Michigan

16. reassessment of data from Republic area

17. Tilden Granite, south of Tilden Mine, Ishpeming, Michigan

18. Tilden Granite, south of Tilden Mine, Ishpeming, Michigan

19. amphibolite gneiss, probable metavolcanic protolith, that overlaps older Southern complex gneiss terrane

20. Southern complex gneisses, northern Michigan

21. felsic metavolcanic rock, Hemlock volcanics, northern Michigan

Marquette Supergroup

22. basalt, Hemlock volcanics, Amasa uplift, Iron County, Michigan

Simmons, 1973): The Bell Creek Gneiss and the Compeau Creek Gneiss, referred to herein as the Compeau Creek South Gneiss to distinguish these older rocks (Hammond, 1976; Peterman and others, 1976) from compositionally similar but younger Compeau Creek Gneiss of the Northern complex. A several kilometer wide zone of migmatitic gneiss surrounds the north and west edge of the Southern complex (Hoffman, 7).

The Bell Creek Gneiss is interpreted as the older of the two major rock types in the Southern complex, and underlies the Compeau Creek South Gneiss (Cannon and Simmons, 1973). It is a coarse grained microcline microperthite - porphyritic adamellite gneiss with subordinate granodiorite, and rare tonalite and granite. A minor part is mafic plagioclase - hornblende - clinopyroxene gneiss. The Compeau Creek South Gneiss, on the other hand, is a foliated, light colored tonalite with potassic phases and minor pegmatites. It has easterly elongate bands of gneissic, plagioclase - amphibole - biotite amphibolite (Cannon and Simmons, 1973). Compeau Creek South Gneiss is 2.75 to 3.50 Ga (Hammond, 1976; Peterman and others, 1976) (table 2-2). The north boundary of the Southern complex with the Marquette Supergroup is interpreted as a steep, crustal scale reverse fault, based on gravity data (Gair and Thaden, 1968; Cannon, 1989, personal communication).

2.2.2 Archean Superior Province Granite - Greenstone Terrane: Northern Complex

Tholeiitic basalt and tholeiitic and calc - alkalic felsic volcanic rocks are north of Southern complex gneiss. The volcanic rocks are intruded by batholithic tonalite bodies (Sims, 1984). There is evidence for sialic crust beneath some greenstone belts in the Great Lakes region, but these rocks probably accumulated mostly on oceanic crust, in the manner of modern oceanic arc complexes (Sims and Peterman, 1981). A 2.640 Ga U - Pb zircon age for amphibolite interpreted as metabasalt, in the Watersmeet dome of Southern complex gneiss, suggests minor overlap of the Superior province volcanic terrane onto the older gneisses to the south (Peterman and others, 1986). Low $^{87}Sr/^{86}Sr$ suggests addition of juvenile, mantle derived material to the crust in the Superior province (Sims and Peterman, 1981). In northwestern Wisconsin and northern Michigan, the Wakefield, Gogebic and Marquette greenstone belts and the granitoid rocks adjoining them are part of the Superior province (Fritts, 1969; Schmidt, 1972; Trent. 1973; Prinz and Hubbard, 1975; Schmidt, 1976; Prinz, 1981; and Sims and others, 1984) (figure 2-2).

The Northern complex (VanHise and Bayley, 1895) extends north and west from Marquette, Michigan over a total of 1025 km^2, of which 300 km^2 is the Marquette greenstone belt and the remainder is foliated tonalite and granodiorite of the Compeau Creek Gneiss (Gair and Thaden, 1968). The Compeau Creek Gneiss is medium to coarse grained, pink to salmon colored foliated tonalite and granodiorite with faint streaky layering. It includes small amounts of monzonite, quartz monzonite, and granite, and widespread but volumetrically minor amounts of amphibolite gneiss. Local septa of amphibolite are interpreted as engulfed remnants of meta - basalt (Gair and Thaden, 1968; Stonehouse, 1970). In the west part of the Northern complex, the foliated granodiorite and tonalite are cut by pink granite and pegmatite. Lack of detailed mapping and poor exposure preclude a precise assessment of the distribution of layered gneiss versus the more massive granites. U - Pb zircon ages from the Compeau Creek Gneiss are 2.700 ± .015 Ga for tonalite and granodiorite, and 2.600 ± .015 Ga for microcline rich

Figure 2-2. Geologic map of the Lake Superior region, with major subprovinces of the Superior province.

(simplified from a compilation by J. W. Norby, Callahan Mining Corporation, from numerous Ontario Geological Survey; U. S. Geological Survey; and Michigan, Wisconsin, and Minnesota state geological surveys sources.)

8. Phanerozoic sedimentary rocks (0.40 - 0.6 Ga)

7. Grenville province (1.0 - 1.1 Ga)

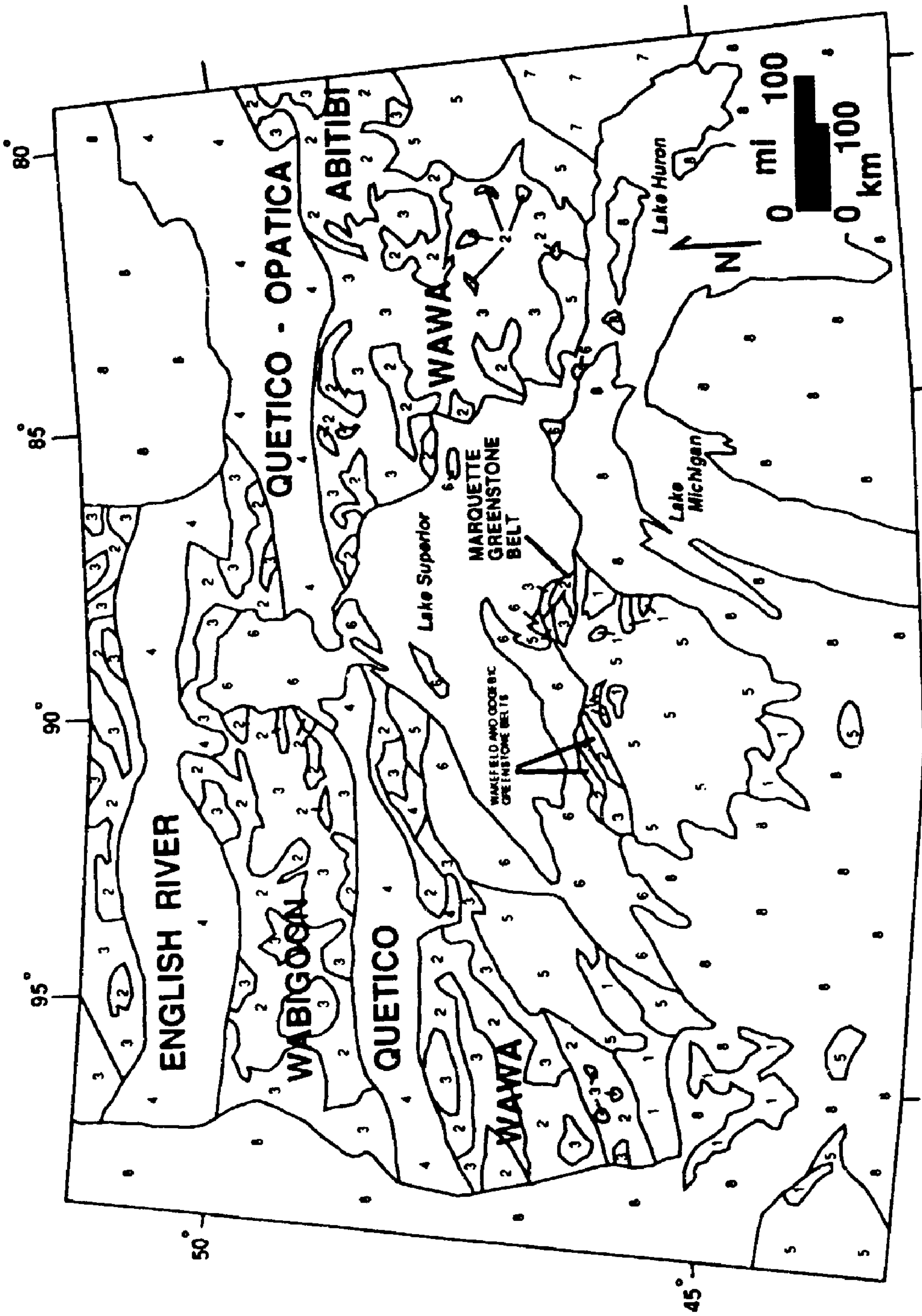
6. Middle Proterozoic mid continent rift and sedimentary and volcanic rocks (1.0 - 1.2 Ga)

5. Lower Proterozoic sedimentary, volcanic, and intrusive rocks (1.8 - 2.1 Ga)

Superior province (2.67 - 3.0 Ga)

4. Sedimentary rocks
3. Granitic rocks
2. Volcanic rocks

1. Southern complex gneiss (2.6 - 3.8 Ga)


ENGLISH RIVER
WABIGOON
QUETICO
WAWA
QUETICO - OPATICA
ABITIBI
WAWA
Lake Superior
MARQUETTE
GREENSTONE
BELT
Lake Michigan
Lake Huron
N
0 mi 100
0 km 100
95°
90°
85°
80°
50°
45°

granite (table 2-2) (Hammond, 1976; Van Schmus, 1978). A substantial part of the Compeau Creek Gneiss may have formed by assimilation of mafic volcanic rocks of the Marquette greenstone belt (Gair and Thaden, 1968). The north boundary of the Marquette greenstone belt is a several kilometer wide igneous contact comprising a zone of lit par lit gneiss and migmatite, and abundant apophyses of Compeau Creek Gneiss extend into amphibolite of the Marquette greenstone belt (Bouley and Hodder, 1987; Small and Bornhorst, 1989). The relative timing of emplacement of at least some of the Compeau Creek Gneiss is constrained to post date extrusion of basalt of the Marquette greenstone belt, by its intrusive relationship with the basalt, and to predate the basal Enchantment Lake Formation of the Lower Proterozoic Marquette Supergroup, which contains foliated tonalite and granodiorite cobbles of Compeau Creek Gneiss.

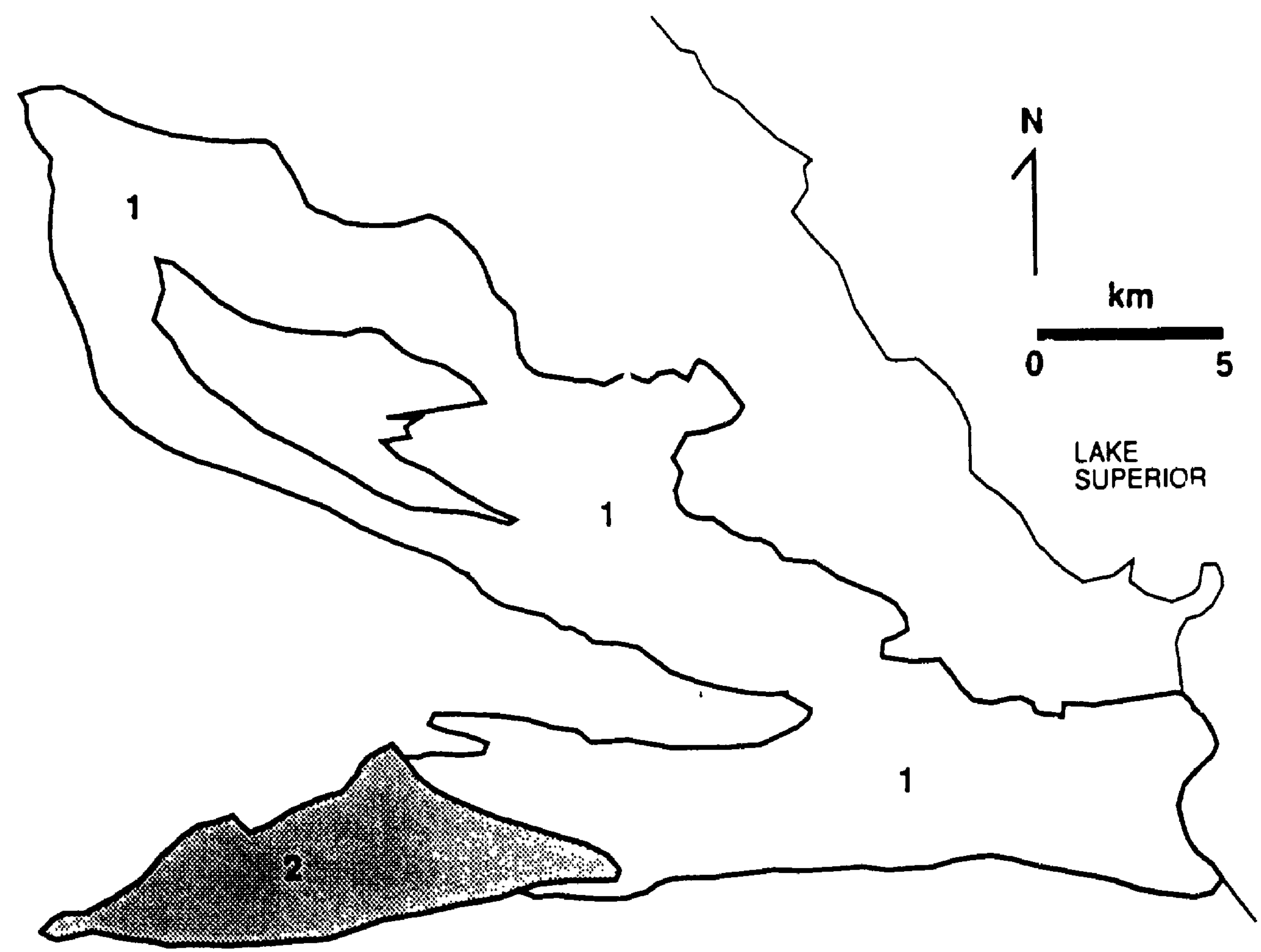
Folds are not common in the Compeau Creek Gneiss, although a major one was mapped by Gair and Thaden (1968) in the Marquette quadrangle north of the greenstone belt. Puffett (1974) mapped a persistent 285° striking, 80° northeast dipping foliation, and northeast and northwest trending silicified zones 10 cm to 1 m wide, which locally host hematite, pyrite and tourmaline, in the Negaunee quadrangle. The Compeau Creek Gneiss is cut by metadiabase and metagabbro dikes interpreted to represent at least five ages of intrusion from Late Archean to Keweenawan based on differing texture, mineralogy, degree of alteration, metamorphism, and deformation within the dikes (Baxter and Bornhorst, 1988). Dextral shear during Late Archean time along the Great Lakes tectonic zone (Sims and others, 1980) may have made a series of low pressure zones which influenced emplacement of the Compeau Creek Gneiss (Palmquist, 1988). The Great Lakes tectonic zone outcrops near Sands Station south of Marquette where it is a zone of mylonitic fabric in gneiss which strikes 290° and dips 75° southwest. Kinematic indicators suggest dextral transpression with a south side up component (Sims, P. K., U. S. Geological Survey, personal communication, 1989). Strain patterns in the Archean Vermillion greenstone belt of Minnesota also indicate dextral transpression (Shultz - Ela, 1986).

The Marquette greenstone belt is subaqueous volcanic rocks and lesser volcanic derived sedimentary rocks originally divided into the Mona Schist and the Kitchi Schist (Van Hise and Bayley, 1985).

Figure 2-3. Original divisions of the Marquette greenstone belt (after Van Hise and Bayley, 1895; 1897; Van Hise, and Leith, 1911).

1. Mona schist: dominantly basalt

2. Kitchi schist: dominantly dacitic fragmental volcanic rocks



MARQUETTE GREENSTONE BELT

Mona Schist is dominantly metabasalt of greenschist and amphibolite metamorphic facies. Kitchi Schist is dominantly fragmental volcanic rocks and volcanic conglomerate of dacite and andesite composition. The belt is interpreted herein as a Late Archean rift phase greenstone belt according to structural criteria consistent with Groves and others (1987), because it is blocks with internally consistent stratigraphic facing directions bound by shear zones. Rocks generally have mineral assemblages of the greenschist facies, except in the north and far southwest parts of the belt in proximity to Compeau Creek Gneiss, where amphibolite facies and upper greenschist facies assemblages, respectively, prevail (table 2-3).

There are a limited number of U - Pb age determinations for rocks in the greenstone belt, including U - Pb zircon ages of 2.700 ± .015 Ga for a quartz porphyritic rhyolite (Hammond, 1976), and 2.650 ± .100 Ga for a quartz - feldspar porphyritic rhyolite (Van Schmus 1974), both from near the Silver Creek prospect in Section 25, T49N, R28W at the south side of the north arm of the belt, and a U - Pb zircon age of 2.700 ± .015 Ga for a porphyritic rhyolite tuff (Van Schmus, 1978) from the bottom of a drill hole through the Early

Table 2-3: Metamorphic assemblages in basaltic rocks in the Marquette greenstone belt (from Johnson and others, 1986).

Metamorphic facies	Mineral assemblage
Upper amphibolite facies	hornblende + calcic plagioclase + diopside
Lower amphibolite facies	hornblende + calcic plagioclase + epidote/clinozoisite
Upper greenschist facies	actinolite + albite + epidote/clinozoisite + chlorite + (almandine) (recrystallized to metamorphic textures)
Lower greenschist facies	actinolite + albite + epidote/clinozoisite + chlorite + (carbonate) (retains magmatic textures)

Proterozoic Clark Creek basin, which presumably overlies rocks of the Marquette greenstone belt (Trow, 1979) (figure 2-5, table 2-2). Younger Rb - Sr whole rock ages for samples of layered amphibolite and a quartz monzonite plug from within the greenstone be'' (Van Schmus, 1974) reflect resetting of isotopic ages. U - Pb zircon ages from the Northern complex of Michigan are therefore 2.7 Ga age, comparable to the Rainy Lake area of the Minnesota - Ontario border, and typical of Archean Superior province granite greenstone belts in the Lake Superior region (Hammond, 1976; Peterman, 1979; Colvine and others, 1988).

The original nature of the boundary between the Southern complex gneiss terrane and the Late Archean Superior province granite - greenstone terrane in northern Michigan is uncertain, because this boundary, marked by the Great Lakes tectonic zone (Sims and others, 1980), was the focus of later extension and deposition of the six kilometer thick Lower Proterozoic Marquette Supergroup, and was reactivated during the Early Proterozoic Penokean orogeny. To the west, in Minnesota, a shallowly north to northwest dipping seismic reflection zone projects to surface near the trace of the Great Lakes tectonic zone, and this is interpreted as a thrust fault or subduction zone caused by Late Archean collision (Gibbs and others, 1984).

2.2.3 Early Proterozoic Marquette Supergroup: Sedimentary, Volcanic, and Intrusive Rocks

The geologic history from the end of volcanism and plutonism in the Archean granite - greenstone terrane, to deposition of the lower part of the Marquette Supergroup may have recorded extension in the Lake Superior region between 2.5 and 2.1 Ga, but rocks formed during this interval are rare in northern Michigan (Sims, 1984). Deposition of the Marquette Supergroup is commonly considered as beginning at approximately 2.1 Ga (Sims, 1984), but this age is poorly constrained. Coarse clastic, graben - like sedimentary deposits such as the Reany Creek Formation, at least partly of Archean provenance (Puffett, 1969) may have formed in either latest Archean or earliest Proterozoic time. The probable age of intrusion of the Tilden granite into the north part of the Southern complex gneiss terrane is 2.345 +/- .020 Ga based on U-Pb zircon ages (Hammond, 1976). Amphibolite, interpreted as metamorphosed basalt which overlaps the Archean Southern complex gneiss terrane, has a U - Pb zircon age of 2.640 Ga (Peterman and others, 1986). Plagioclase porphyritic diabase dikes cut Archean structural trends at a high angle and are tentatively correlated with the Late Archean Matachewan dike swarm of Ontario on the basis of texture, but there are no age determinations from local sites (Baxter and Bornhorst, 1988).

The Marquette Range Supergroup (table 2-1) is three upward fining megacycles: the basal Chocolay Group, with dolomite; the middle Menominee Group, capped by the major Negaunee Iron Formation; and the upper Baraga Group, which has alternating slates and iron formations, bimodal basalt - rhyolite volcanism of the Clarksburg Volcanics, and is graywacke in its upper part. Earlier workers (Cannon and Gair, 1970) considered the Marquette Supergroup a passive continental margin extensional sequence, but there is now a consensus that these rocks formed in deepening marine troughs (Sims, 1984). Early Proterozoic rifting resulted in sedimentation in structural troughs in which rocks of the Marquette Range Supergroup are preserved. Structural troughs existed during Early Proterozoic sedimentation, as documented by the restriction of basal conglomerates to the troughs, and by analysis of paleocurrent indicators which indicate current flow parallel to the present axes of the troughs (Larue, 1979, 1981; Larue and Sloss, 1980). Collision with the volcanic arc of the Wisconsin magmatic terrane to the south resulted in the Penokean orogeny (Cambray, 1977, 1978; Larue 1979; Larue and Sloss, 1980; Larue, 1981).

Schulz and others (in press) propose that the Marquette Supergroup was deposited on rifted crust developed over the Great Lakes tectonic zone (Sims and others, 1980) between older Archean Southern complex gneiss terrane and the Late Archean Superior province granite - greenstone terrane, and that subsequent southward directed subduction at approximately 1.83 to 1.89 Ga (Van Schmus and Bickford, 1981) led to the formation of a complex oceanic island arc system represented by tholeiitic basalt, calc - alkalic andesite to rhyolite, calc - alkalic gneiss, and tonalite to granite of the Wisconsin magmatic terrane. Continued subduction resulted in eventual collision of the arc with the Archean crust of northern Michigan (Cannon, 1973; Schultz and others, in press). The rarity of Penokean plutonic activity in the Archean Superior province craton to the north and its common presence in the Archean Southern complex suggests that the subducting plate during Penokean time was south dipping (Van Schmus and others, 1987).

Hoffman (1988) proposed that the Marquette Supergroup represents a Penokean foredeep sequence deposited on down flexed Archean crust between the Penokean fold belt to the south, which was related to accretion of the Early Proterozoic island arc magmatic terrane of central Wisconsin, and an Archean foreland to the north. In his model, the Chocolay Group is a passive margin accumulation, bounded by an upper disconformity caused by foreland directed migration of a flexural forebulge; the Menominee Group is a strandline (Ajibik Quartzite) to foreslope (Siamo Slate) to starved outer ramp (Negaunee Iron Formation) accumulation; and the Baraga Group is turbidites deposited along the axial zone of the foredeep. The Baraga Group was also deposited farther north in shallower basins on the Archean foreland as the south edge of the Archean Superior province crust was depressed by loading (Hoffman, 1988), represented by up to 2 km thick Lower Proterozoic rocks of the East Baraga, Dead River, and Clark Creek basins (Trow, 1979; Cannon, 1977). The upper part of the Baraga group is foredeep deposits derived from the Wisconsin magmatic terrane to the south during the Early Proterozoic Penokean orogeny (Barovich and others, 1989).

Reactivation of Archean basement in the Marquette trough was along discrete high angle faults in both the Archean Superior province and Archean Southern complex rocks from Marquette to Ishpeming (Cannon and Gair, 1970; Cannon, 1973), but deformation was more ductile in the Southern complex gneiss in the Republic trough and Watersmeet dome 80 km further west (Klasner, 1978). Closure of the Marquette trough by north northeast directed transpression resulted in sinistral shear along the margins of the trough, indicated by structural analysis of strain indicators in pre - Keweenawan, post Marquette Supergroup Proterozoic mafic dikes (Cambray, 1984). Persistent 110° striking, 50° southwest dipping axial planar slaty cleavage in the Dead River, Clark Creek, and East Baraga basins is also consistent with north northeast directed Penokean compression (Trow, 1979). Steep, east striking faults in the Marquette Supergroup have dip displacements of up to 760 m and strike displacements of up to 1370 m (Brown, 1986a).

A major metamorphic episode in the Marquette trough was probably related to Penokean deformation, and some workers map a node of sillimanite isograd in the Republic trough (James, 1955; Cannon, 1975; Brown 1986a), ringed concentrically outward by lower metamorphic grade rocks. Recent work, however, indicates only widespread biotite zone greenschist facies and local amphibolite facies assemblages in the Lower Proterozoic rocks, with evidence for garnet zone or higher assemblages restricted to migmatitic Archean Bell Creek gneiss of the Southern complex (Longiaru, 1989), hence the regular metamorphic zonation (James, 1955) may not exist. Rocks in the Marquette trough are generally below biotite isograd in the Ishpeming area. Younger Rb - Sr mineral ages of approximately 1.650 Ga (table 2-2) in Southern complex gneiss of the Republic area reflect internal re - equilibration of the Rb - Sr system during a post Penokean metamorphic event (Van Schmus, 1974; Van Schmus and Woolsey, 1975).

The age of the Marquette Supergroup is not well constrained. One sample from the Hemlock volcanics has a U - Pb zircon age of 1.985 Ga (table 2-2). The Hemlock volcanics are probably correlative with the Negaunee sills and with minor volcanic rocks in the Negaunee Iron Formation (table 2-1). Six types of basalt sills and flows in the east part Marquette trough all have greenschist or epidote amphibolite facies mineral assemblages. The relative timing of intrusion and extrusion of these igneous rocks is contemporaneous with Negaunee Iron Formation time (Mathias, 1959).

2.2.4 Middle Proterozoic Keweenawan Diabase Dikes, Peridotite and Sandstone

The Midcontinent rift system, which extends north from central Kansas, east through Lake Superior and south through southern Michigan, is marked by voluminous clastic sedimentation and basaltic volcanism at about 1.225 to 1.110 Ga (Wold and Hinze, 1982). In the Marquette area, the most important manifestation of Keweenawan rifting within Archean rocks was widespread emplacement of diabase dikes with generally north and east strikes. Minor Keweenawan gravity faulting occurred parallel to some of the diabase dikes (Trow, 1979). The north trending Keweenawan dikes are cross cut by the east trending Keweenawan dikes. The dikes are fine - grained hypabyssal basalt with unoriented laths and euhedral prisms of ferroan olivine, with titaniferous augite and ilmenite in interstitial spaces. Except for thin seams of iron oxides, the dikes are unmetamorphosed. The easterly striking layering of the rock types and structural grain in the Superior province exercised a major control on the orientation of the north part of the Midcontinent rift where it transects rocks of the Superior province (Klasner and others, 1982).

Upper Keweenawan Jacobsville Sandstone onlaps the east and northeast sides of the Archean Northern complex near Marquette. It is fluvial feldspathic and quartzose sandstones, conglomerates, siltstones, and shales (Kalliokoski, 1982).

Two peridotites are generally considered of Keweenawan age: 1.) The Presque Isle Peridotite in Marquette is post Marquette Supergroup, pre Keweenawan or Keweenawan in age, based on the presence of considerable preserved olivine and pyroxene (Gair and Thaden, 1968; Lewan, 1972). It contains foliated zones of serpentine and therefore may be deformed. 2.) The Yellow Dog Peridotite is a partly serpentinized peridotite of probable Early Keweenawan age (Morris and Wilband, 1977; Klasner and others, 1979a). It outcrops in two places along a 20 km long by 1 to 2 km wide zone marked by positive aeromagnetic anomalies within the Yellow Dog Plains north of the Marquette greenstone belt. The rock was originally a plagioclase lherzolite. Texturally the rock is relatively fresh and undeformed, therefore it probably post dates the Penokean Orogeny (Klasner and others, 1979a).

2.3 Geology of the Marquette Greenstone Belt

The Late Archean Marquette greenstone belt (Brozdowski and Bouley, 1989) outcrops over an area of 300 km^2 in a west opening V, with its apex at Lake Superior within the city of Marquette. It has a maximum north - south dimension of 24 km and an east - west dimension of 35 km (figure 2-4, map plate 1), and is variably metamorphosed and deformed basalt, with subordinate fragmental dacite, and minor amounts of sedimentary rocks derived from felsic and mafic volcanic rocks. Various workers have mapped parts of the belt but there is only one brief journal paper (Morgan and DeCristoforo, 1980), and no comprehensive synthesis of the geology.

Figure 2-4. Major geologic features of the Marquette greenstone belt. (Modified from Brozdowski and Bouley, 1989). Shear zones (S.Z.) which bound geologic blocks are indicated by thick shaded lines.

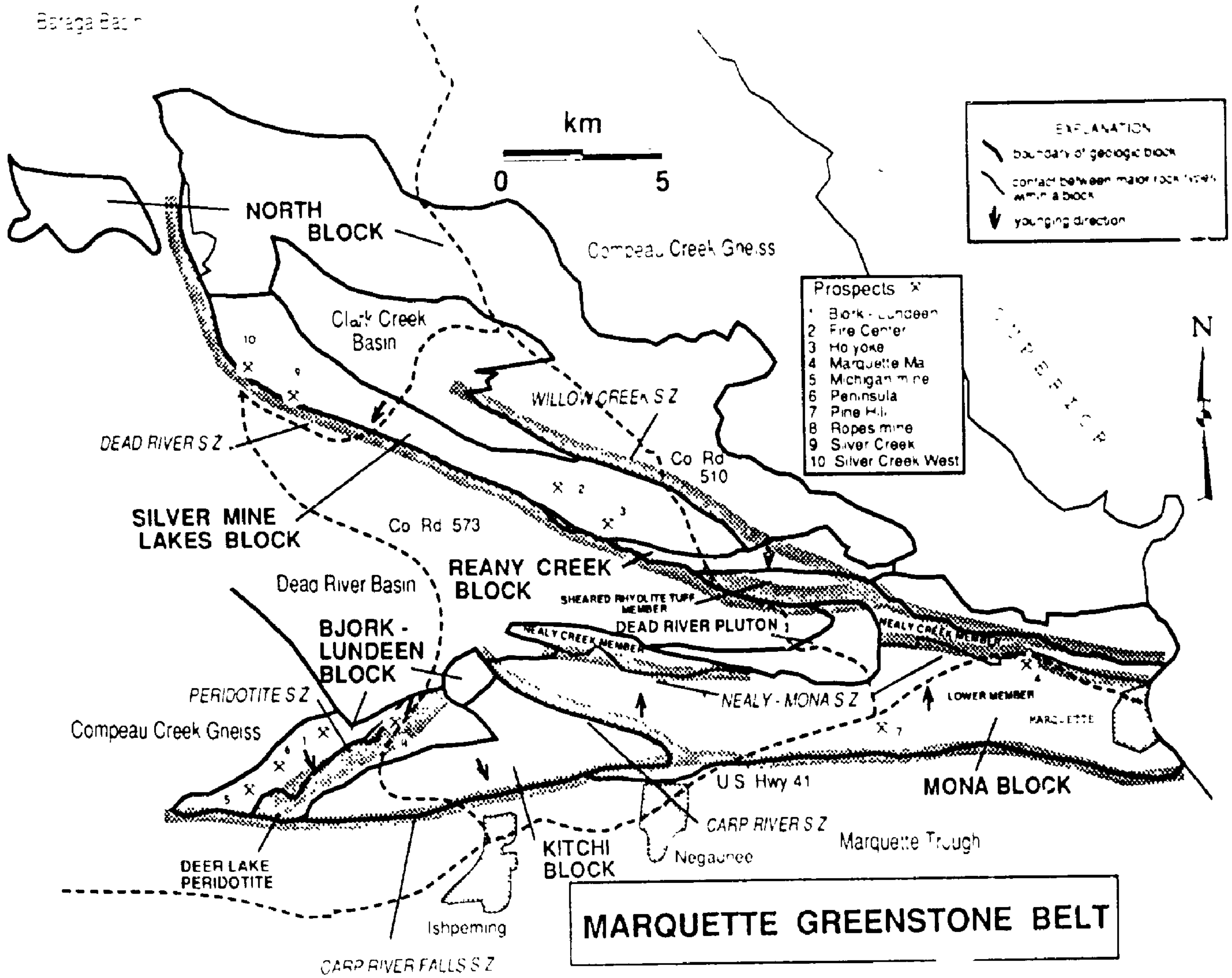

Baraga Basin
km
0
5
NORTH BLOCK
Compeau Creek Gneiss
EXPLANATION
boundary of geologic block
contact between major rock types within a block
younging direction
Prospects "X"
1 Bjork - Lundeen
2 Fire Center
3 Holyoke
4 Marquette Ma
5 Michigan mine
6 Peninsula
7 Pine Hill
8 Ropes mine
9 Silver Creek
10 Silver Creek West
N
Clark Creek Basin
WILLOW CREEK S Z
Co Rd 510
DEAD RIVER S Z
SILVER MINE LAKES BLOCK
Co Rd 573
REANY CREEK BLOCK
Dead River Basin
SHEARED RHYOLITE TUFF MEMBER
DEAD RIVER PLUTON
NEALY CREEK MEMBER
BJORK - LUNDEEN BLOCK
PERIDOTITE S Z
NEALY - MONA S Z
LOWER MEMBER
Compeau Creek Gneiss
U S Hwy 41
MONA BLOCK
CARP RIVER S Z
Marquette Trough
DEER LAKE PERIDOTITE
KITCHI BLOCK
Negaunee
Ishpeming
CARP RIVER FALLS S Z
MARQUETTE GREENSTONE BELT

Figure 2-5. Radiometric age determinations in the Northern complex, Marquette greenstone belt and surrounding rocks.

Sources of U-Pb age determinations on zircons:

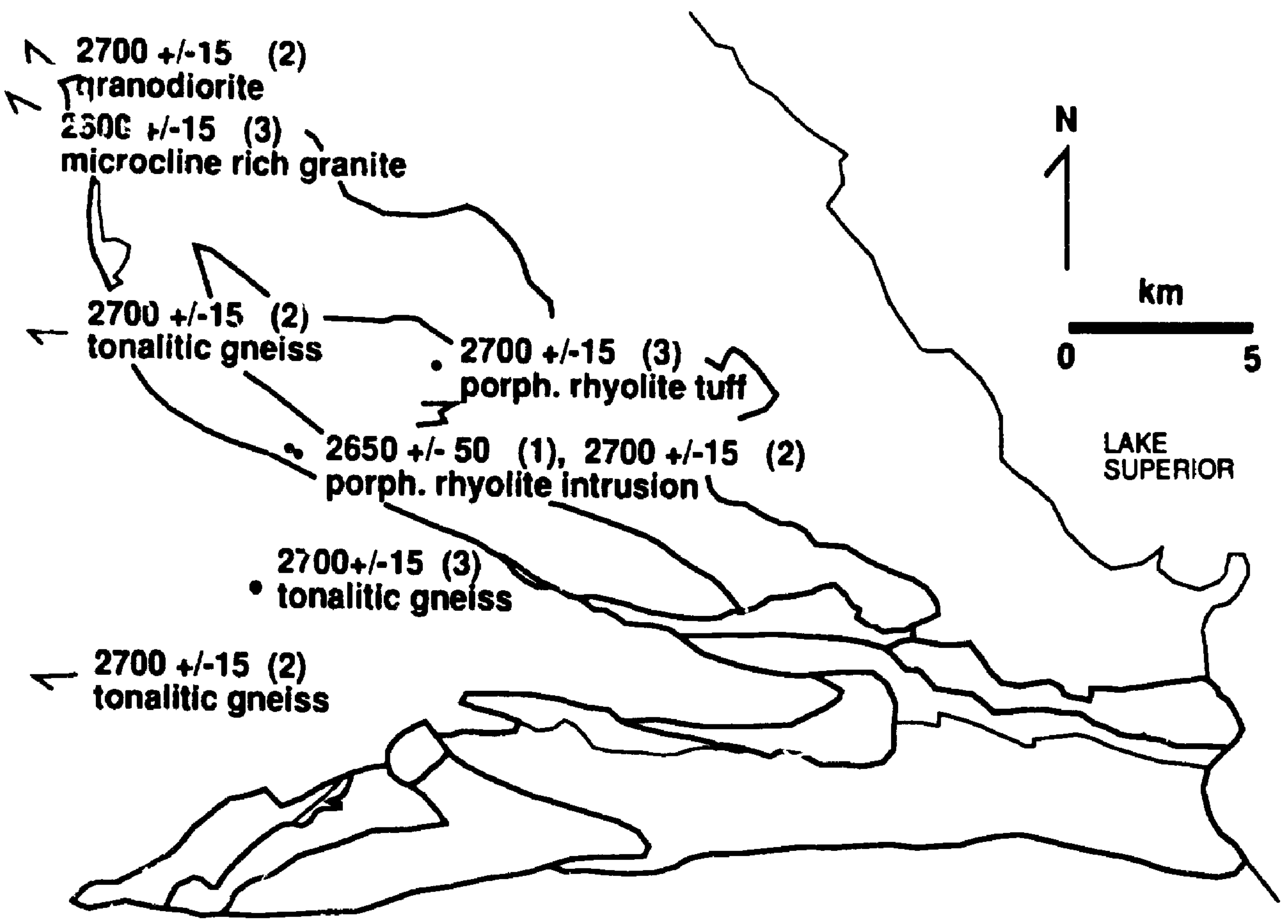
(1) Van Schmus, 1974

(2) Hammond, 1976

(3) Van Schmus, 1978

o denotes location of sample

√ denotes location of sample is off map to west



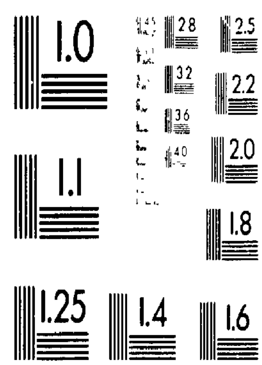
Radiometric Age Determinations, my (U -Pb Zircon)

Marquette Greenstone Belt and Northern Complex

Rocks in the Marquette greenstone belt have mineral assemblages of the lower to middle greenschist facies, except where there is amphibolite facies against the Compeau Creek Gneiss in the far north and upper greenschist facies in the far southwest parts of the belt. Rocks of the greenschist facies have a sub vertical planar foliation, defined by a slight parallelism of aphanitic phyllosilicate minerals. Primary structures such as flow contacts in volcanic rocks, graded bedding in graywackes, and compositional layering in rocks such as chert - magnetite iron formation are readily discernable. There are relict cumulate textures in serpentinitic peridotite, pillows in basalt, and bipyramidal and embayed quartz grains, and lithic fragments in dacite tuffs (plate 2-1). Hence, the rocks are referred to herein by their sedimentary or igneous names as recommended in the North American Code of Stratigraphic Nomenclature; the prefix meta is implied. Primary bedding and pillow features allow reconstruction of stratigraphic facing directions.

In my geologic synthesis, the Marquette greenstone belt is east to southeast trending, steeply dipping basalt flows, fragmental dacite, and volcanic derived sedimentary rocks intruded by fine

2



2

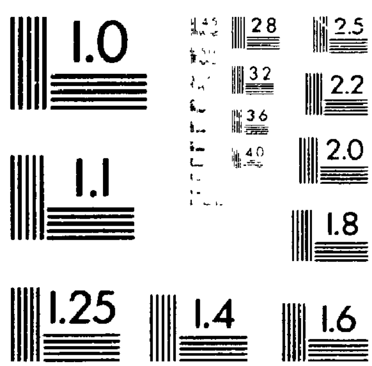


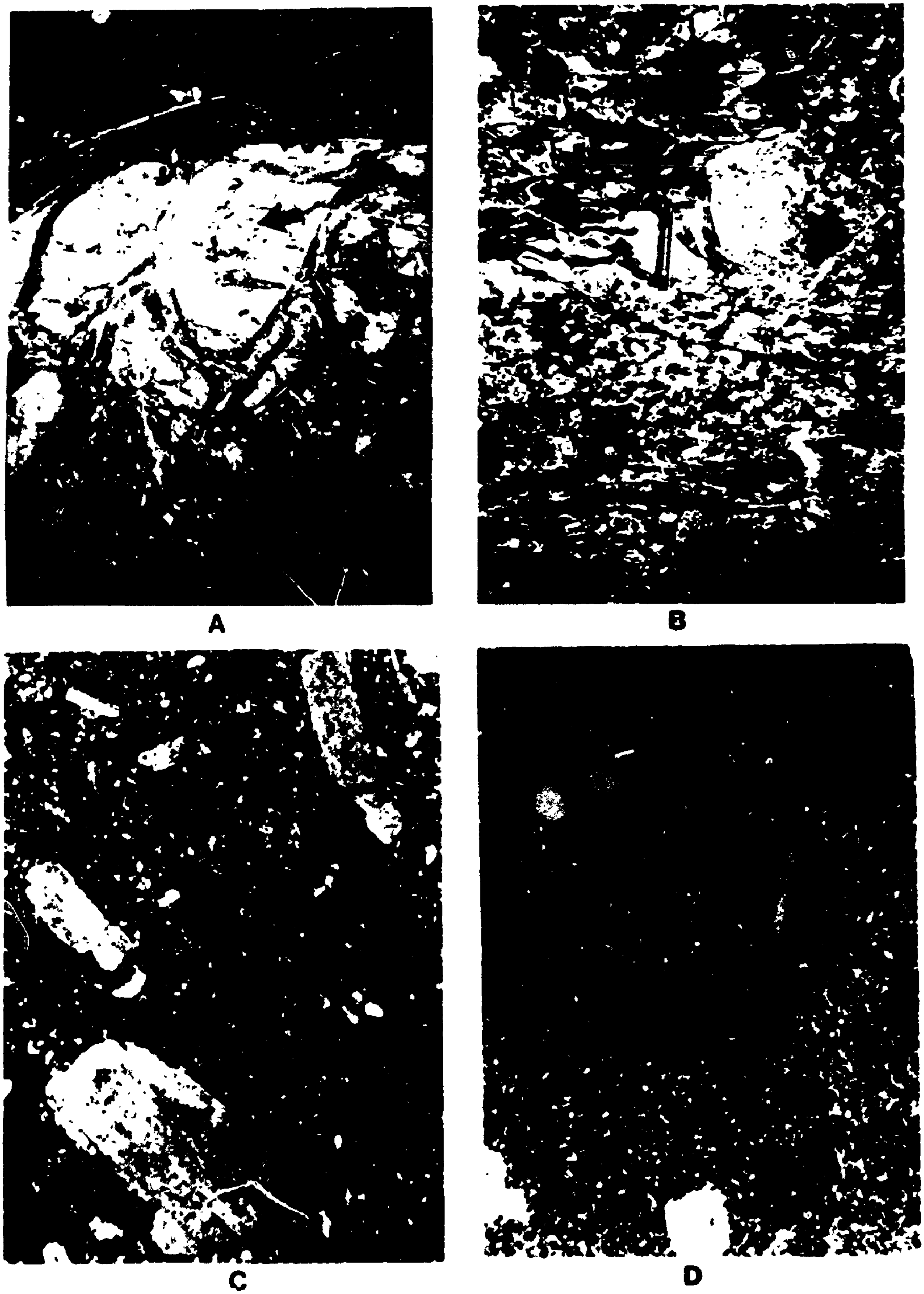
Plate 2-1. Rocks from Marquette greenstone belt, depicting primary volcanic features.

a. Pillowed basalt of the Lower Member of the Mona block, with cuspate bases and bulbous tops indicating north younging direction (arrow) Hammer is 30 cm. (SW1/4 NW1/4 Section 19 T48N R25W).

b. Dacite tuff breccia in Kitchi block, with both subrounded clasts and large angular polygonal clast. Scale is 15 cm. (NE1/4 Section 27 T48N R27W).

c. Dacite crystal tuff with feldspar phenocrysts (f) in feldspar rich groundmass, west of Ropes deposit. Photomicrograph is 2 mm across short dimension, in cross polarized light (NE1/4 Section 29 T48N R27W).

d. Dacite crystal tuff west of Ropes deposit with twinned feldspar (f) and bipyramidal quartz (q) in aphanitic quartz - feldspar - sericite groundmass. Photomicrograph is 2 mm across short dimension, in cross polarized light (NE1/4 Section 29 T48N R27W).



A B C D

grained gabbro and rhyolite dikes and sills. There is a large mass of serpentinitic peridotite in the southwast part of the belt, and a composite granodiorite - syenite pluton in the central part of the belt. Magnetically, the belt is characterized by low to moderate amplitude, one to several kilometer long, discontinuous easterly trends with up to 1000 gammas positive magnetic relief which generally parallel layering between volcanic rock types in the belt. The south side of the north arm of the belt, the Silver Mine Lakes block, is a west - northwest trending kilometer wide band with magnetic relief 1000 gammas greater than the rest of the greenstone belt. The Deer Lake Peridotite in the southwest part of the belt has positive magnetic relief of up to 7000 gammas (Case and Gair, 1965; Anzman, J., 1988).

The regional tectonic setting of the Marquette greenstone belt differs from most Archean Superior province greenstone belts in the Canadian shield in that it has been reactivated in the Proterozoic as relatively uplifted blocks, bounded by troughs of Lower Proterozoic Marquette Supergroup sedimentary rocks. These Proterozoic sedimentary basins have steep, fault bounded north sides, and less steep south sides which, except in the case of the Marquette trough, are generally depositional angular unconformities.

2.3.1 Divisions of the Marquette Greenstone Belt

The Marquette greenstone belt is various blocks, bound by shear zones, (figure 2-4) with each of the blocks defined by rock suites with internally consistent stratigraphic facing directions, and a consistent major rock type or interlayered sequence of rock types, and differing concentrations, sizes, and styles of gold occurrences.

1.) The Bjork - Lundeen block (figure 2-7; map plate 2) is a southeast facing sequence with a base of tholeiitic basalt intruded by gabbro and rhyolite dikes and sills, transitional upward through interlayered basalt and dacite into a dacite pyroclastic section which hosts minor quartz - magnetite iron formation and quartzose graywacke. Texturally distinct glomerophyric basalt flows are near the transition from basalt to dacite. Most known gold occurrences are within the Bjork - Lundeen block, including the Ropes mine and

Peninsula prospect zones of dispersed pyrite with gold and the Bjork - Lundeen prospect and Michigan mine quartz veins.

2.) The Kitchi block is southeast facing volcanic conglomerates, mud flow breccias, and tuffs of dacite to andesite composition, with features indicative of a water reworked pyroclastic origin. Only a few minor gold prospects on quartz veins are known in the Kitchi block.

3.) The Deer Lake Peridotite is a large sill like serpentinitic peridotite body with smaller subsidiary sills, and contacts locally interlayered with volcanic rocks of the Bjork - Lundeen block.

4.) The Mona block is north facing pillowed and massive tholeiitic basalt of the Lower Member, with thin tuffaceous and carbonaceous sedimentary interflow horizons, topped by chloritic to sericitic slates of the Nealy Creek Member, and rhyolite tuff of the Sheared Rhyolite Tuff Member. Gold in the Mona block is with quartz veins in carbonaceous interflow sediments, in fractured and quartz - veined gabbro sills, and with pyrite in carbonate rich zones in basalt.

5.) The Silver Mine Lakes block is south facing Fe to Mg tholeiitic basalt intruded by gabbro and rhyolite sills and dikes. It has subordinate dacite fragment rich mudflow breccias and minor banded quartz magnetite iron formation in the lower part of the block. There is minor dacite tuff in the southwest part. The Silver Mine Lakes block contains the majority of known gold occurrences outside of the Bjork - Lundeen block. Gold with dispersed pyrite is in chlorite - sericite - quartz rich zones within broader carbonate rich areas in basalt, commonly along the brecciated margins of porphyritic rhyolite sills and dikes, and also in minor quartz veins.

6.) The North block is transitional Fe to Mg tholeiitic basalt and gabbro sills, metamorphosed to amphibolite grade in its northern two - thirds. There are only minor gold showings with quartz veins. The northeastern part is not mapped.

7.) The Reany Creek block, of questionable Late Archean or possibly Early Proterozoic age, is south facing conglomerate, slate, turbiditic graywacke, and arkose.

8.) The Dead River Pluton is a composite granodiorite - syenite pluton which intrudes the Nealy Creek Member of the Mona block.

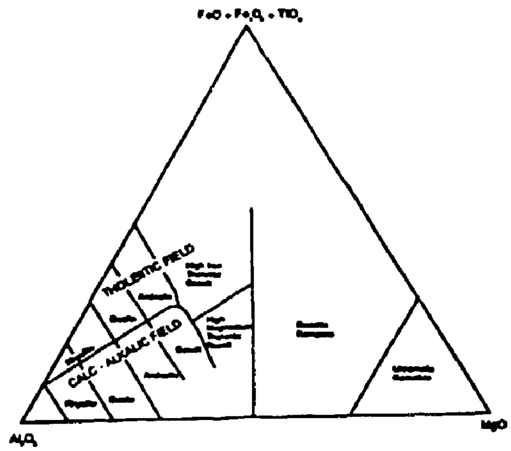
Jensen cation plots (appendix A) of rocks from the Marquette greenstone belt have differing concentrations of rock types in different blocks of the belt, although the rocks plot along the same overall geochemical trend (figure 2-6): 1.) The Silver Mine Lakes and Bjork - Lundeen blocks range from high Fe - tholeiitic basalt to calc - alkalic rhyolite; 2.) The Kitchi block is mostly calc - alkalic dacite and andesite; 3.) The Northern block is transitional Fe to Mg tholeiitic basalt with rhyolite sills; and 4.) The Mona block is mostly borderline Fe to Mg tholeiitic basalt.

Blocks are bound by linear zones of phyllonitic rocks, accompanied by linearly arrayed zones of secondary carbonate, chlorite, sericite, hematite, or pyrite. These features are interpreted as shear zones. (figure 2-4, plate 2-2a,b). There are major changes in rock type and in stratigraphic facing direction across these shear zones, thus correlation between blocks is not possible.

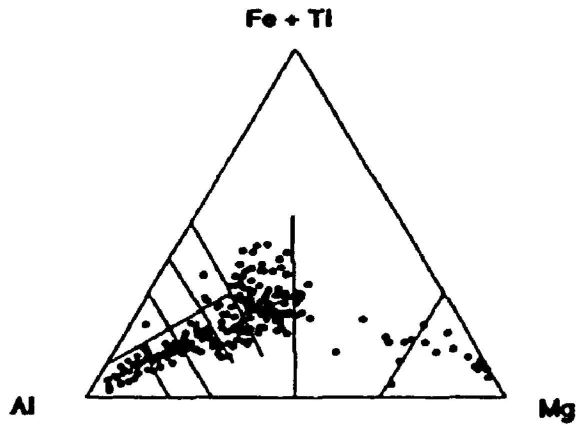
Figure 2-6. Jensen cation plots for volcanic and subvolcanic rocks from the Marquette greenstone belt.

(Analyses of whole rocks plotted include categories 5, 2, 1.5 and 1 from compilation in Appendix B, but exclude rocks in those categories from within the Ropes gold deposit)

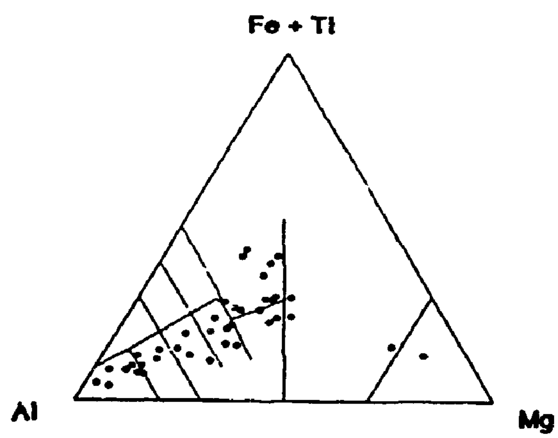
Compositional fields are from Jensen (1976). Jensen plot routine for Macintosh Excel written by B. A. Bouley.



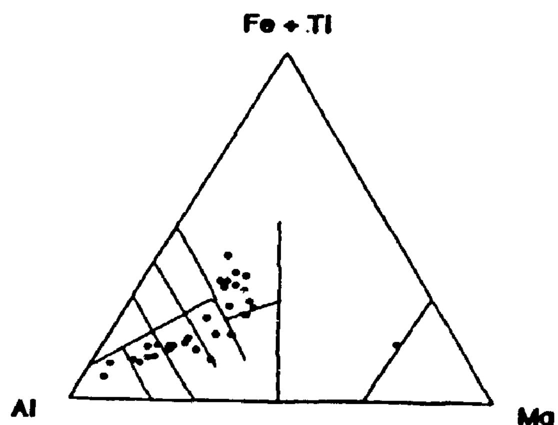
Jensen Cation Percentage Plot



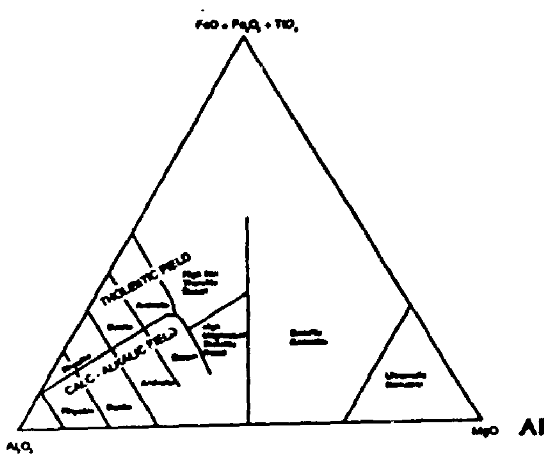
MARQUETTE GREENSTONE BELT



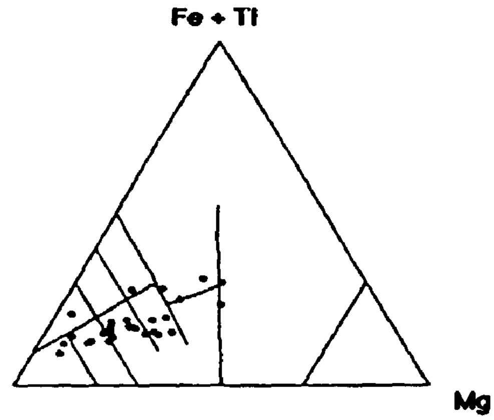
SILVER MINE LAKES BLOCK



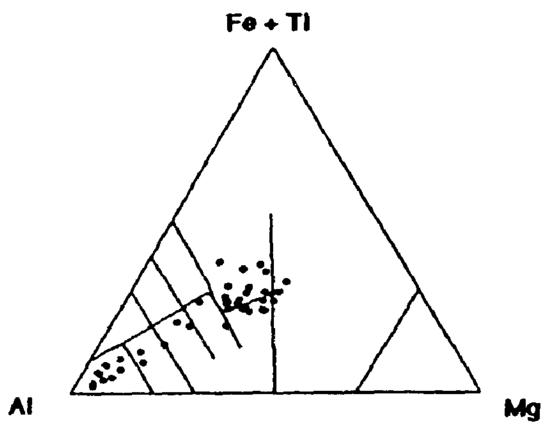
BJORK - LUNDEEN BLOCK



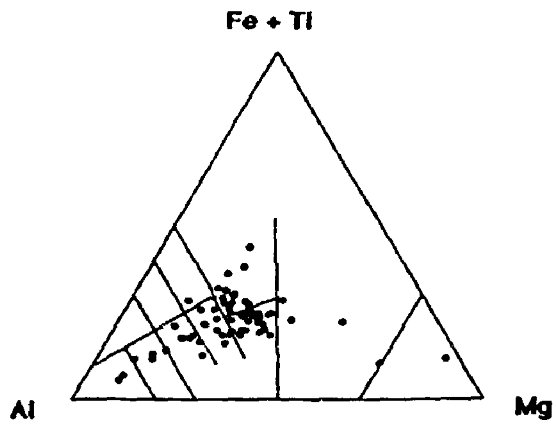
Jensen Cation Percentage Plot



KITCHI BLOCK



NORTH BLOCK



MONA BLOCK

2.3.1.1 The Bjork - Lundeen Block

The Bjork - Lundeen block, named after the gold bearing quartz vein prospect near its center, is a sequence of pillowed basalt flows and relatively thinner massive basalt flows of tholeiitic composition, interlayered in its upper part with dacite tuff, and subordinate flows of dacite and andesite. The dacite hosts minor quartzose graywacke and banded iro formation. Medium grained gabbro sills and dikes and three small granodiorite plugs intrude the basalts (map plate 2). The sequence is intruded by fine grained feldspar porphyritic rhyolite dikes and sills, which also locally cut the gabbros. Strike is east northeast to northeast with steep south to vertical dips. Shapes of pillows in basalt flows and graded beds in minor graywackes define a southeast facing direction. The Bjork - Lundeen block was included by Cannon and Klasner (1975) as part of the Kitchi Schist.

Basalts are plagioclase, actinolitic hornblende, clinozoisite, actinolite, and chlorite with minor to accessory sphene, leucoxene, calcite, magnetite and quartz. Biotite, and to a lesser extent hornblende partly occupied by chlorite, are in some samples.

Plate 2-2.

A. Phyllonitic basaltic rock along Carp River Falls shear zone. Hammer is 40 cm. (SE1/4 SW1/4 Section 29 T48N R26W).

B. Minor high strain zone in Lower Member of Mona block north of Carp River Falls shear zone, with boudinaged quartz - carbonate vein indicating vertical extension. Hammer is 40 cm. (NE1/4 SW1/4 Section 28 T48N R26W).

C. Heterolithic tuff breccia in Kitchi block, south shore of Deer Lake with mostly rounded clasts. Darker clasts are andesite, light colored clasts are rhyodacite, dacite clasts are difficult to distinguisn from groundmass. Meter sized clasts are at left center of photograph. Scale at left center is 15 cm (SE1/4 NE1/4 S33 T48N R27W).

D. Monolithic tuff breccia in Kitchi block, with elongate fragments of rhyodacite. Scale is 15 cm. (SE1/4 Section 27, T48N, R27W).

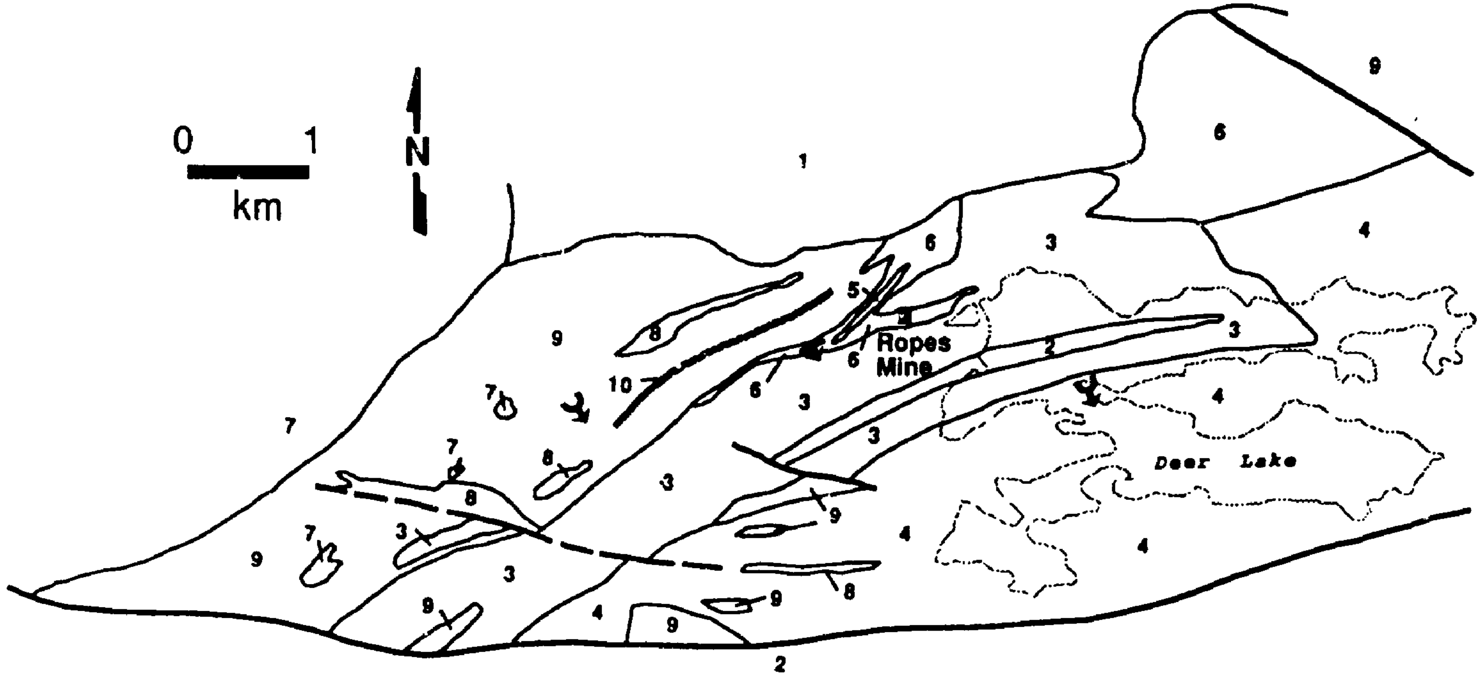
A

B

C

D

Figure 2-7. Simplified geologic map of the southwest part of the Marquette greenstone belt.



EXPLANATION

PROTEROZOIC
- 1 graywacke and slate
- 2 quartzite

ARCHEAN
- 3 serpentinitic peridotite
- 4 volcanic conglomerate, subordinate dacite tuff
- 5 banded iron formation and graywacke
- 6 dacite tuff, tuff breccia and flows
- 7 tonalite and granodiorite
- 8 gabbro
- 9 basalt
- 10 glomerophyric basalt

Domains with external habits like plagioclase laths or microlites and mafic minerals, interpreted as relict magmatic textures, are common, and there are epidote - quartz - calcite pillow rims. The rock ranges from isotropic to slightly foliated. Certain tabular layers within the basalt sequence are possibly volcaniclastic sediment derived from basalt, consistent with their increased magnetite content and slightly layered structure (Norby, 1988a). The medium grained gabbros have identical mineral assemblages to the basalts, except that they consist of crudely rectangular plagioclase subhedra of uniform size with interstitial mafic domains of actinolitic hornblende, clinozoisite, actinolite, and chlorite pseudomorphic after original pyroxene. One major and one minor horizon of glomerophyric basalt have scattered subhedra of plagioclase phenocrysts up to 2 cm across (plate 2-3a). These occur near the top of the basalt section in the Bjork - Lundeen block, within 100 m of the transition into dacite (map plate 2), as is common within tholeiitic to calc - alkalic volcanic cycles in Archean greenstone belts (Green, 1975) The major 30 m thick glomerophyric flow can be traced for over 2.5 km in outcrop and drilling (map plate 2). Mafic volcanic rocks in the far southwest part of the Bjork - Lundeen block have metamorphic textures in thin section, and mineral assemblages of upper greenschist facies. Thin sills of serpentinitic peridotite with talc and carbonate minerals are near the Bjork - Lundeen prospect (Norby, 1988a). These are probably sills outlying to the Deer Lake Peridotite.

Dacite crystal lithic tuff has angular fine grained quartz, plagioclase, and very fine grained quartz - sericite - plagioclase clasts, with relatively few mafic domains, in a matrix of aphanitic ouartz, plagioclase, and sericite (plate 2-1c,d). Sericite rich laminae are common. Dacite flows are massive, with felted bundles of plagioclase laths in an aphanitic matrix of quartz and sericite with variable proportions of biotite, epidote, chlorite, calcite, and pyrite.

Banded iron formation is small polygonal grains of quartz with layers of alternating fine granular magnetite and actinolite, with calcite, or alternatively chlorite (plate 2-2b). Immature graywacke is plagioclase clasts, lithic fragments, abundant quartz and minor mafic domains. Millimeter scale layering is common, with fine grained angular quartz rich laminae alternating with aphanitic quartz - plagioclase - sericite - chlorite rich laminae (plate 2-3b).

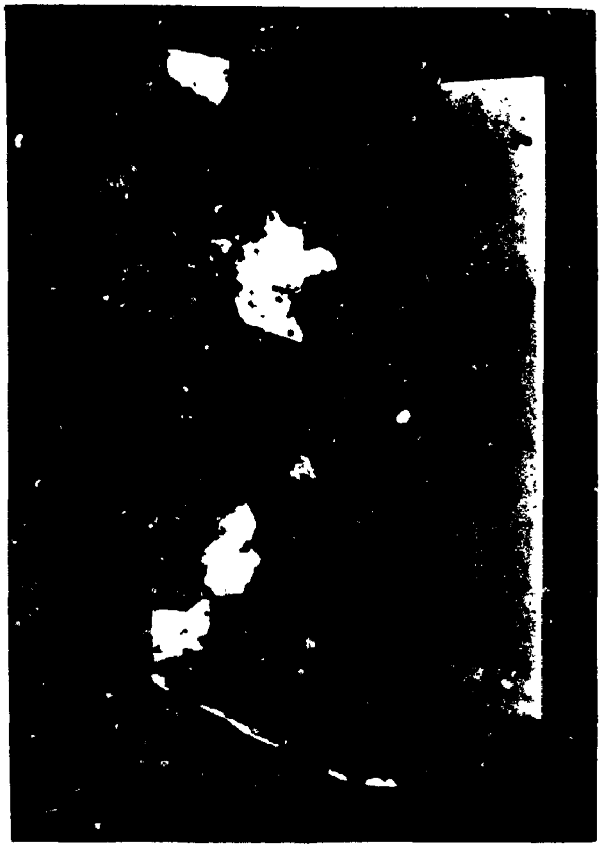
Plate 2-3. Rocks from Bjork - Lundeen block west of Ropes deposit. Scale bars are in cm.

A.) Glomerophyric basalt with clusters of feldspar phenocrysts (NE1/4 Section 30 T48N R27W).

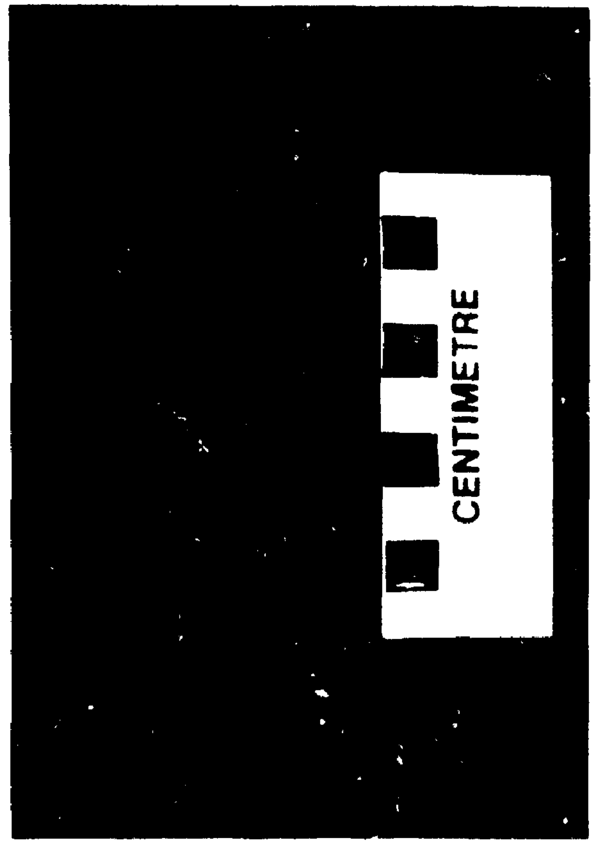
B.) Banded quartz - magnetite iron formation from west of Ropes deposit. Bright spots and wisps parallel to bedding are pyrite. (NE1/4 Section 29 T48N R27W).

C.) Graywacke from west of Ropes deposit (NE1/4 Section 29 T48N R27W).

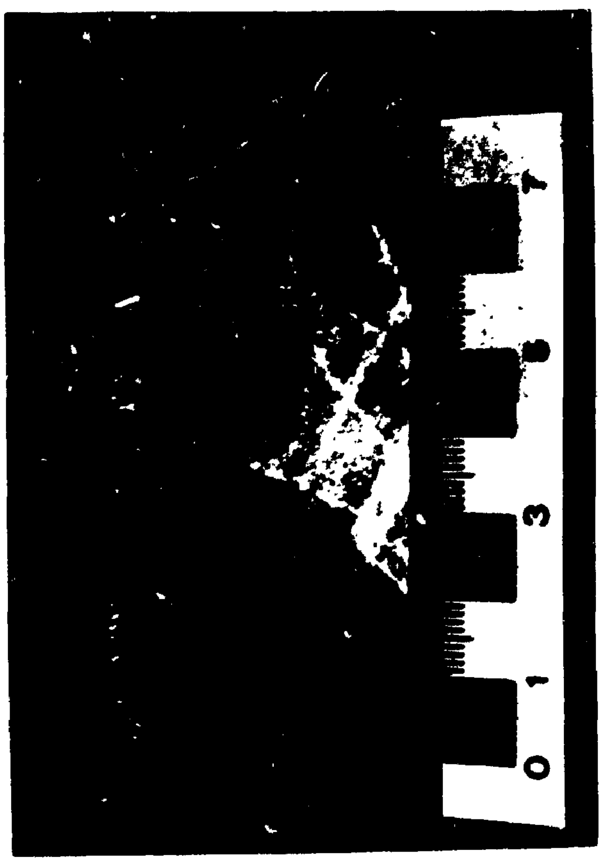
D.) Heterolithic tuff breccia from west of Ropes deposit, with angular clasts marked by arrows. (NE1/4 Section 29 T48N R27W).



A



B



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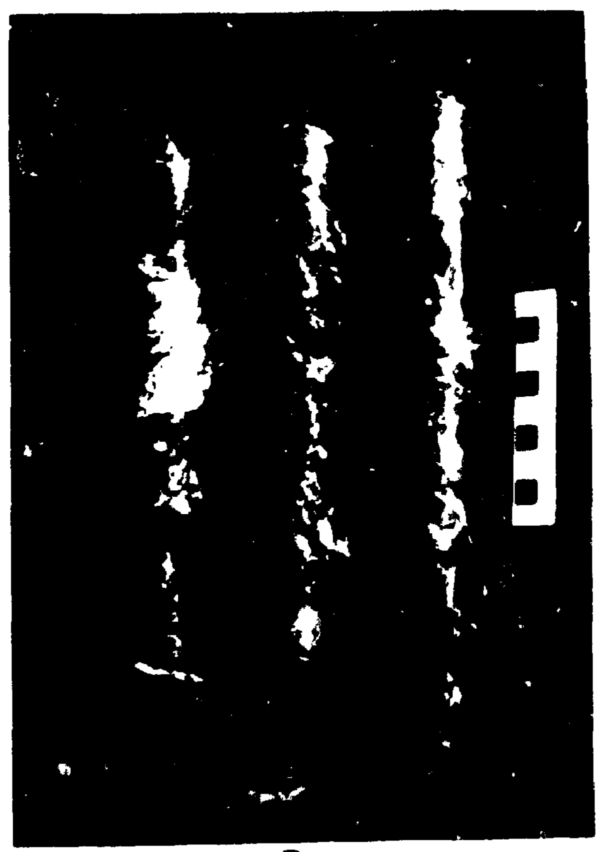


D

Graywacke most commonly occurs immediately below iron formation. Banded iron formation, along with pillowed basalts, are evidence of subaqueous deposition.

Minor andesite is near the basalt to dacite transition west of the Ropes deposit, and is phenocrysts of plagioclase and clots of clinozoisite and chlorite with accessory sphene, which appear to wholly pseudomorph original pyroxene, in an aphanitic quartz rich matrix. Granodiorite intrudes as small plugs and is rectangular plagioclase subhedra with interstitial quartz, chlorite pseudomorphic after hornblende, and calcite and minor pyrite along cracks and cleavages.

The Bjork - Lundeen block (figure 2-4; map plate 2) is bound on the west by granodiorite and tonalite of the Compeau Creek Gneiss, on the southwest by Lower Proterozoic Ajibik Quartzite along the Carp River Falls shear zone, on the north by the north dipping unconformity with the Lower Proterozoic Goodrich Quartzite, and on the south and east by serpentinitic Deer Lake Peridotite. The contact with granodiorite and tonalite to the west is sharp, and may be faulted (map plate 2), in contrast to the broad lit par lit contact of the greenstone belt against the Compeau Creek Gneiss along the north side of the greenstone belt.

2.3.1.2 Kitchi Block

The Kitchi Block is dacite and derivative rocks southeast of the Deer Lake Peridotite, north of the Carp River Falls shear zone, and southwest of the Carp River shear zone which forms the boundary between the Kitchi block and the Mona block (figure 2-4). Age relations between the Kitchi block and the Mona block are equivocal. Morgan and DeCristoforo (1980) speculated that the Mona block overlies and is therefore younger than the Kitchi block, however, there is no evidence for this because the north younging Mona block and the southeast younging Kitchi block have opposite facing directions across the Carp River shear zone (map plate 1; figure 2-4).

The Kitchi block is subequal amounts of tuff breccias and tuffs of dacite and andesite composition, with easterly trends (Hagni, 1954). The tuff breccias are dominantly subrounded fragments of dacite, andesite, and rhyodacite ranging in size from 1 m down to sub mm size and averaging 5 cm in diameter, in a matrix of sharp edged plagioclase fragments and fine felted chlorite, sericite, and calcite (plate 2-2 c,d). A subordinate number of fragments are subangular and platy in shape (plate 2-2d), or are sharp cornered polygons (plate 2-1b). Some layers commonly have greater than 50% fragments which weather white to pink and are lighter in color than the groundmass. The groundmass is andesine and orthoclase, partly altered to sericite. Andesine uncommonly has albite and Carlsbad twinning. Chlorite pseudomorphs crystal shapes of primary pyroxene, or forms six sided shapes after basal sections of hornblende. Fine grained chlorite, sericite, epidote, and calcite, or ferroan dolomite, are in the groundmass along with sparse quartz. Wedge shaped leucoxene replaces sphene (Hagni,1954). The fragments are of quartz or feldspar porphyritic dacite tuff, dacite flow, and andesite flow (plate 2-2c). The fragments are similar in appearance to the dacite flows and tuffs west and north of the Ropes deposit in Sections 29 and 30, T48N, R27W, and may have been derived from similar terrane. Tuff breccias are interpreted as water reworked volcanic conglomerates and mud flow breccias (Hagni, 1954). They have a groundmass interpreted as devitrified glass with some broken crystals with ragged outlines and subordinate angular lithic fragments. Abundance of subrounded and rounded clasts, local sorting into alternating fragment rich and fragment poor layers, graded bedding, and lack of spindle shaped bombs or chilled surfaces on bombs suggests at least some reworking by water. The lack of cataclastic structures along the margins of fragments suggests that fragments were rounded by water transport or abrasion during eruption or mass transport and not by tectonic shearing. Rare pillowed basalt flows with the tuff breccias are consistent with southeast facing directions indicated by graded bedding, as well as with subaqueous deposition of the rocks (map plate 2).

Fine grained zones with sparse or absent fragments are interlayered with the volcanic conglomerates (map plate 2). Their composition is identical to the groundmass of the volcanic conglomerates, and they are interpreted as crystal and crystal lithic dacite tuffs. They generally do not have gradations in grain size and therefore may not have been reworked by water.

Bedding in the Kitchi block, as defined by variation in fragment size and local pillowed basalt flows, trends east northeast to east.

Foliation strikes nearly east and generally dips steeply south. It is typically not pronounced and chlorite plates in the matrix are not aligned. If there is no repetition of the section, the Kitchi tuff breccias and tuffs may be up to 4500 m thick.

Several observations suggest but do not require that the Kitchi block be younger than the Mona block: 1.) Tholeiitic basalt in the Bjork - Lundeen block is interlayered in its upper part with dacite tuff and tuff breccia. This basalt has an identical southeast facing direction to rare pillowed basalts in the Kitchi block, and the Bjork - Lundeen block may have originally directly underlain the Kitchi block prior to emplacement of the Deer Lake Peridotite. The basalt base of the Bjork - Lundeen block is transitional Fe to Mg tholeiitic basalt, comparable to basalt in the Mona block. If chemically similar basalts in the Bjork - Lundeen block and Mona block formed contemporaneously, then the tuff breccia of Kitchi block may overlie them and be younger. 2.) Foliation is generally less prominent in the Kitchi block, as chlorite platelets are less well aligned than in the Mona block. 3.) There are fewer dikes of basalt or rhyolite in the Kitchi block, and, 4.) Granodiorite of the Dead River Pluton, which intrudes the Mona block, is the compositional equivalent of dacite to high silica andesite of the Kitchi block (Hagni, 1954).

Kitchi tuff breccias are not equivalent to Reany Creek Formation or Early Proterozoic Enchantment Lake Formation which differ vastly from the Kitchi in fragment composition and have more pronounced bedding (Hagni, 1954).

2.3.1.3 Deer Lake Peridotite

The Deer Lake Peridotite (DLP)(Morgan and DeCristoforo, 1980) outcrops within an east northeast trending belt 0.8 km wide by 8.5 km long (figure 2-4; map plate 2). It is a homogeneous, dark green to gray rock which lacks regular layering or mineral zoning. It is mainly fine grained to aphanitic serpentine, with accessory secondary magnetite and locally abundant dolomite veins. It has only very local, thin layers of serpentinitic pyroxenite up to several cm thick. Most of the DLP has 1 to 3 mm serpentine pseudomorphs after olivine and pyroxene. No primary olivine or pyroxene remains. The pseudomorphs are rimmed by dolomite, magnetite, and talc. Serpentine in former olivine domains generally points toward grain centers or is unoriented, whereas in former pyroxene domains, serpentine follows a prominent cleavage direction, along with subparallel trains of fine grained magnetite, in a bastite texture which contains scattered pennine.

Volumetrically minor parts of the DLP are yellow - green to dark green, very fine grained, felted massive to well foliated serpentinite without relict igneous textures. Dark gray to dark green serpentinitic peridotite with relict igneous textures is largely chrysotile and lizardite with minor antigorite, whereas, green felted to foliated textured serpentinite contains relatively more antigorite (Rossell,1983). The presence of antigorite is characteristic of prograde metamorphism or serpentinization at higher pressures and temperatures than chrysotile (Moody, 1976). Rossell (1983) interpreted the protolith of the DLP as harzburgite and lherzolite based on plotting the mineral norms from volatile free analyses of whole rocks on an olivine - orthopyroxene - clinopyroxene ternary diagram.

The DLP has minor SiO_2, TiO_2, Al_2O_3 and Sc, but enhanced MgO, Cr and Nb, relative to pyroxene rich extrusive komatiites, diagnostic of intrusive ultramafic rocks with a primary mineralogy dominated by olivine (R. Kerrich, personal communication). The fine grained relict cumulate texture also supports an intrusive origin. No spinifex texture, flow contacts, or polysuturing suggestive of an extrusive origin for the DLP were observed.

The DLP has carbonate and talc along its north contact with enclosing basalt and dacite, known from drilling near the Ropes deposit. Elsewhere, along the north side of the DLP in Section 27, T48N, R27W, the contact with dacite is a meter wide zone of actinolite - chlorite schist. Dacite tuff and tuff breccia have more chlorite and quartz veins near the contact with the DLP.

Dacite tuff which hosts the Ropes deposit is one of six known localities where tabular to wedge shaped bodies of volcanic rocks are interlayered or interdigitated with serpentinitic peridotite (map plate 2). Other volcanic inliers may exist in till covered low ground. The DLP separates dominantly basalt on the northwest side of the DLP, from dacite volcanic conglomerate and dacite tuff on the southeast side. Contacts of the DLP are conformable with individual volcanic horizons where known in detail from drilling and surface mapping, but cut across the overall northeast trending interlayered basalt to dacite transition at an acute angle (map plate 2). The southeast side of the DLP is in fault contact with an elongate wedge of Lower Proterozoic Ajibik Quartzite. The contact is not exposed, but blocks of float on an island of Ajibik Quartzite in Deer Lake, Section 28, T48N, R27W, are soft limonitic gossan with fragments of carbonate - rich serpentinite breccia and fragments of Ajibik Quartzite . A subtle zone of relatively lower total magnetic field compared to serpentinitic peridotite trends west southwest for 3 km from the island toward outcrops of Ajibik Quartzite in SE 1/4 Section 29, T48N, R27W (Callahan Mining Corporation, unpublished ground magnetic survey), and this is interpreted as an unexposed continuation of the quartzite (map plate 2). The overall map trend of the DLP is 058°, and its northwest margin is parallel to a prominent topographic lineament on aerial photographs named the I-18 structure (Lehnertz, 1987).

The generally well preserved pseudomorphic igneous textures in the DLP, and the interlayered relationship of the serpentinitic peridotite with the enclosing volcanic rocks along its north contact, suggest that it was intruded as a sill complex. Minor serpentinitic peridotite sills intersected by drill holes at the Bjork - Lundeen prospect (Norby, 1988a) 500 m north of the main DLP may be part of the complex.

The generally internally massive and texturally isotropic DLP has a random network of narrow, anastamosing curvilinear fractures, filled with chrysotile asbestos, interpreted as hydration fractures, but otherwise is not pervasively deformed internally on a mesoscopic scale . The edges of the DLP have a greater magnetic susceptibility than its center, probably reflecting more magnetite immediately inward from its border of carbonate - talc rock. Internal to the DLP, serpentinitic peridotite which retains relict magmatic textures forms magnetically and topographically high lenses which are bounded by carbonate - talc rock. The DLP may have been intruded along a northeast trending early structure or zone of weakness which follows the transition from basalt to dacite.

2.3.1.4 Mona Block

The Mona block (figure 2-4) is pillowed to massive basalt in the south part, with subordinate chloritic and sericitic slate in its north part. It includes the Lower, Nealy Creek and Sheared Rhyolite Tuff members of the Mona Schist (Puffet,1974).

The Lower Member of the Mona block is 2100 to 3300 m of pillowed and massive basalt and subordinate medium grained gabbro sills and dikes of transitional Fe to Mg tholeiitic composition. Pillowed basalt is commonly variolitic. Interflow horizons host minor basalt tuff or foliated basalt, dacite tuff, chlorite to sericite slate, lean cherty banded quartz - magnetite iron formation, hematitic chert, and local saccharoidal layers of ferroan dolomite - quartz rock which are parallel to the foliation (map plate 1a). Volcanic rocks in the Lower Member of the Mona block strike east to east southeast and dip 70° north to vertical. Pillows face consistently to the north and average 0.3 to 1 m in their long axes.

Basalts are green to gray green, aphanitic to fine grained with variable chlorite, pale green actinolite, 1 mm twinned and untwinned laths of sodic plagioclase, sericite, and epidote/clinozoisite. Sodic feldspar is probably pseudomorphic after more calcic primary plagioclase, based on the basalt composition of the rocks. Some of the plagioclase is occupied by epidote and sericite. Quartz, magnetite, leucoxene, sphene, and carbonate are generally minor. Locally, especially near interflow rocks, calcite content of the rock is sufficient to provide a strong reaction to dilute HCl. In more foliated varieties of basalt, chlorite is more abundant at the expense of tremolite - actinolite. Amygdules are filled by variable mixtures of calcite, chlorite, epidote, sphene, and leucoxene. Pillow interstices are filled by milky to cherty quartz, calcite, and epidote, and commonly contain minor pyrite and trace chalcopyrite. The rocks are within the chlorite zone of the greenschist facies.

In areas of good local exposure, there are complete gradations from massive, unpillowed inner parts of a flow, northward through upward increasing abundance of pillows and decreasing pillow size, into a zone of angular basalt clasts in a fine grained matrix, which is flow top breccia. Fine to medium grained gabbro is compositionally identical to the basalt. It is stubby rectangular plagioclase of uniform size, with interstices filled by splintery actinolite accompanying domains of original mafic minerals, and minor sphene.

Foliated mafic rocks, largely of chlorite and calcite, with minor plagioclase, quartz, leucoxene, and sericite, may represent zones of greater strain within basalts, or alternatively they may be basalt tuffs that have accommodated later deformation because of their originally more layered nature. The latter explanation is considered more likely in instances where these zones of foliated rock also host lean banded quartz - magnetite iron formation and dacite tuff, which is plagioclase and quartz crystal clasts in a matrix of sericite, dolomite, and quartz. Zones of foliated mafic rock are commonly sites for intrusion of fine grained gabbro sills. Elongate rod like structures in pillow rims marginal to foliated zones have length to width of up to 10:1 in a near vertical orientation and are interpreted as strained varioles in basalt. Foliated zones also host quartz veins with minor chalcopyrite (Puffett, 1966a, b). Other zones of foliated basalt are accompanied by quartz boudins elongate in the down dip direction (plate 2-2b), have a near vertical mineral lineation, and contain pillow structures that are very elongate in a steep down plunge direction. Slaty, foliated basalt, unaccompanied by felsic rocks or chert, is most common within the lower part of the Lower Member, immediately north of the mapped trace of the Carp River Falls shear zone (plates 2-2a) (Brozdowski, 1987).

The Nealy Creek Member (Puffett, 1974) is chlorite to sericite slates from 90 m thick at the east to 900 m thick at the west end of its outcrop area. The rocks are green, moderately schistose to slaty and have 0.1 to 0.5 mm angular quartz granules and 0.2 to 0.5 mm feldspar in an aphanitic matrix of aligned sericite and chlorite. (Puffett, 1974). The average composition is 27% quartz, 44% sericite and sericite rich feldspar, and 29% chlorite (Puffett, 1974). Biotite is prevalent as fine grained, unoriented laths in the contact aureole of the Dead River Pluton (Gleason, 1986). Accessory minerals include zircon, apatite, tourmaline, epidote, and pyrite. Although stratigraphic facing indicators such as graded bedding or pillow cusps were not noted in the Nealy Creek Member, it is included here in the Mona block because: (1) it is texturally and compositionally similar to slates which are within the Lower Member to the south; (2) the transition between the Lower Member and the Nealy Creek Member, although structurally disturbed, has interlayered pillowed basalt and chlorite - sericite slate with local ferruginous chert and thin jasper - like iron formation and appears to be depositionally transitional; and (3) the Lower Member and Nealy Creek Member are of similar lower greenschist facies metamorphic grade, as opposed to the amphibolite of the North block. Gair and Thaden (1968) interpret the Nealy Creek Member as water laid tuff, whereas Puffett (1974) ascribes its origin to an airfall tuff. Lack of distinctive bedding or layering features, and slaty cleavage, particularly near its contact with the Lower Member, obscures the nature of its protolith . A rhyodacite composition is reported for one sample (Puffett, 1974).

The contact of the Nealy Creek Member and the Lower Member is a high strain zone (Puffett,1974; Gleason 1985). Rocks along this contact are best exposed in Marquette south of the Marquette Mall as quartz veined, hematite and carbonate - rich variolitic basalt overlain by very fine grained to aphanitic chlorite - sericite - quartz slate. At the Zhulkie Creek prospect in Section 15, T48N, R27W, pyritic quartz - carbonate veins and graphitic carbonate - chlorite - quartz rocks are within slates of the Nealy Creek Member, and pyritic, siliceous slates are near the contact of the Nealy Creek Member with the Lower Member at McClure Storage Basin (Gleason, 1985). Persistent slaty cleavage in open, near vertically plunging folds at the Nealy Creek and Lower Member contact indicate that this zone is deformed. Isoclinally folded, thin ferruginous chert outlines meter scale folds near the Marquette Mail prospect.

The Sheared Rhyolite Tuff Member is quartz rich rock with layering interpreted as well developed vertical foliation (Puffett, 1974). The rock is pink to green - gray rhyolite, with phenocrysts of glassy quartz and pink to cream feldspar in a groundmass of aphanitic quartz, sericite, and minor chlorite (ibid.). Ten to fifty percent of the rock is 0.2 to 2 mm quartz, elongate parallel to the foliation. Feldspar phenocrysts are occupied by sericite and are 0.4 to 2 mm in size. Green wafers up to .5 cm thick and 1.5 cm long, 2/3 sericite and 1/3 iron - rich chlorite, are interpreted as altered lapilli (Puffett, 1974). The Sheared Rhyolite Tuff Member ranges from 100 to 300 m thick. It may grade into intermediate to mafic rock of the Nealy Creek Member to the east, and on this basis it is included here in the Mona block.

The Mona block is bound to the south by an unconformable contact with the Lower Proterozoic Enchantment Lake Formation along the Carp River Falls shear zone, a structure with near vertical foliation and a local vertical to steep east plunging mineral lineation. Steeply south dipping Lower Proterozoic rocks face back to back with the north facing, vertical to slightly overturned pillowed basalt of the Lower Member of the Mona block. Foliation in basalt and cleavage in the Enchantment Lake Conglomerate are nearly parallel, and the rocks have a pronounced mineral lineation in the down dip direction consistent with nearly vertical movement (Gair and Thaden, 1968). A nearly consistent thickness of the basal Proterozoic Enchantment Lake Conglomerate along most of the Carp River Falls shear zone (Gair and Thaden, 1968; Puffett, 1974) indicates that Archean and Proterozoic rocks were not tectonically intermixed.

Finite strain analysis of varioles in pillowed basalts in the Lower Member of the Mona block indicates 25 to 40% north - south horizontal shortening, 40 to 70% vertical lengthening, and little or no east - west length change (Carter, P., 1989). More than one deformation is not indicated for Lower Member pillowed basalt (ibid.). The symmetries and orientations of the finite strain ellipsoid in the Lower Member pillow basalts are similar to those derived for the Lower Proterozoic Enchantment Lake Formation, Mesnard Quartzite, Kona Dolomite, and Ajibik Quartzite (Westjohn 1978, 1986, 1987; Carter, P., 1989) making it uncertain whether strain indicators in the pillows are a result of Archean or Proterozoic deformation.

Fine grained quartz - sericite - carbonate rock in the Carp River Falls shear zone is best exposed in an east striking zone 420 m southeast of the U. S. highway 41 Carp River crossing in Section 29, T48N, R26W and also 900 m west along U. S. highway 41 from the same Carp River crossing. These rocks contain embayed quartz phenocrysts and tabular feldspars in a fine grained matrix of granoblastic to foliated grained quartz, feldspar, sericite and carbonate with minor epidote, chlorite and rare biotite. The quartz phenocrysts are fractured and local granoblastic mosaics of quartz may also have been quartz phenocrysts. South of these exposures, the Carp River Falls shear zone is up to 400 m wide and is chlorite - quartz and sericite - quartz - chlorite slates of presumed Archean age. There are lenses of saccharoidal quartz and ferroan dolomite with pyrite up to 1 meter thick parallel to the foliation, mostly near the north contact of the Carp River Falls shear zone where it grades into increasingly less deformed pillowed basalt.

The east part of the north boundary of the Mona block is the up faulted contact with the Reany Creek block; and farther east it is in contact with amphibolite of the North block. The west part of the north boundary is the Dead River Pluton, which intrudes the Nealy Creek Member and Lower Member, as indicated by a biotite hornfels contact aureole adjacent to the pluton (Gleason, 1985). The far northwest contact of the Mona block is an unconformity with Lower Proterozoic Goodrich Quartzite. This contact is folded and faulted into east trending, west plunging folds. The southwest boundary of the Mona block is along a northwest trending linear zone of no outcrop which follows the Carp River. There are opposed stratigraphic facing directions in the Kitchi and Mona blocks across what is herein termed the Carp River shear zone, which forms the boundary between the southeast facing dacite tuff and dacite volcanic conglomerate of the Kitchi block and the north facing basalt of the Lower Member of the Mona block. Northeast and southwest margins of the zone are foliated rocks and host lenses of quartz and ferroan dolomite up to 50 cm thick and several meters long.

Several outliers of basalt and chlorite - quartz - sericite schist which form the cores of anticlinal structures within the Lower Proterozoic rocks of the Marquette Supergroup are south of the east end of the greenstone belt, and these are included in the Lower Member by Gair and Thaden (1968). In the Harvey Quarry south of Marquette, one such outlier has a well developed foliation cut by a later steeply dipping crenulation cleavage. The early foliation is interpreted as Archean, and the later crenulation cleavage as Penokean (Kangas and Brown, 1986).

2.3.1.5 Silver Mine Lakes Block

The Silver Mine Lakes block (SMLB) is southwest facing, mainly pillowed to massive basalt. There is minor dacite tuff in the upper part of the block near the Silver Creek West prospect in its southwest part. In its lower part, the block has minor mudflow breccia with clasts of dacite and cherty iron formation, as well as thin banded iron formation. Major gabbro sills crosscut the east southeast striking layered volcanic sequence along two southeast trends in the central and the east parts of the block, and sporadically at the west end of the block. The volcanic rocks are cut by major to minor quartz and feldspar porphyritic rhyolite sills and dikes which post date the gabbro, and also by small unfoliated granodiorite plugs which are mostly in the upper part of the block in the Silver Creek West and Fire Center - Holyoke areas, (figure 2-8; map plate 1a). The rocks are mostly at greenschist facies of regional metamorphism except along the north margin of the block where there is local amphibolite hornfels (Bouley and Hodder, 1987).

Basalt is albite, chlorite and epidote with actinolitic hornblende in the coarser varieties plus locally carbonate, sericite, and pyrite. Chlorite is in domains pseudomorphic after original mafic minerals and saussurite is after calcic plagioclase. Epidote - chlorite rich pillow rims are common. Much of the carbonate, sericite and pyrite within basalt is at the margins of rhyolite sills, and at the margins of a branching rhyolite sill at the Silver Creek prospect. Foliated zones of chlorite - quartz - sericite phyllite are

Figure 2-8. Simplified geologic map of the Silver Mine Lakes block.

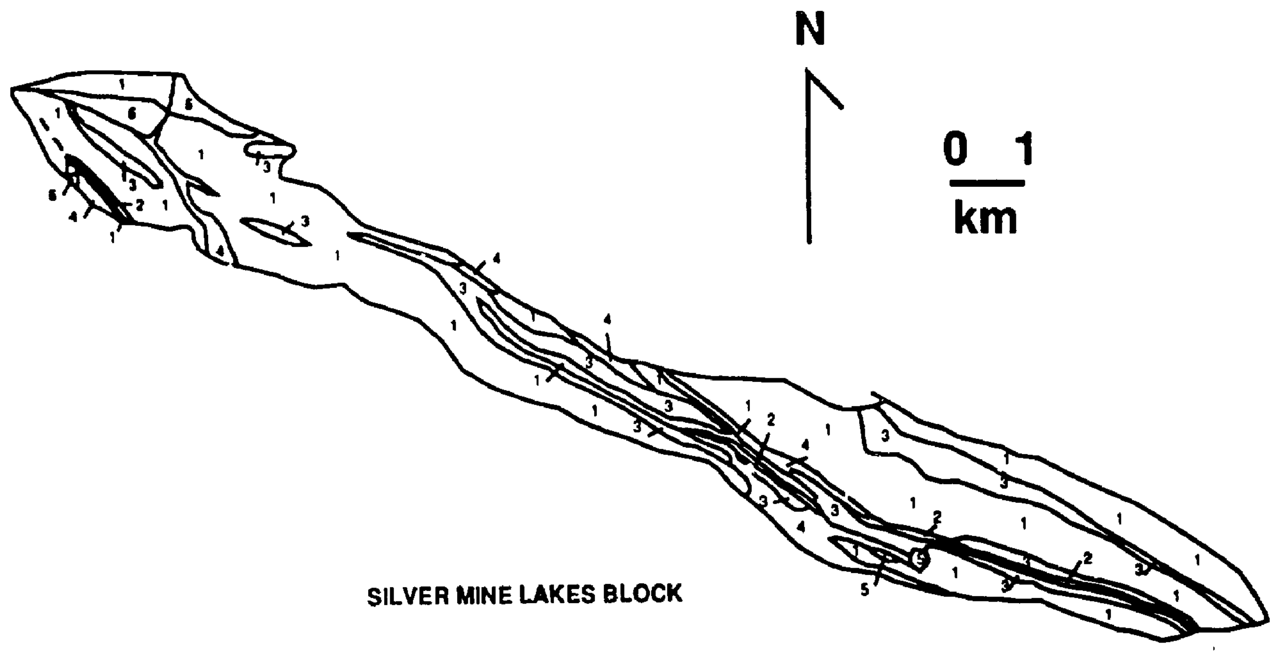
5. Granitoid

4. Rhyolite sills, minor dacite

3. Gabbro sills

2. Iron formation

1. Basalt



SILVER MINE LAKES BLOCK

common in basalt north of the Dead River shear zone, and these are interpreted as sheared basalt.

Gabbro sills and dikes have sharp contacts with basalt, and fine grained margins. They are medium to coarse grained hypidiomorphic blue - green amphibole, chlorite, and lesser light gray plagioclase, with trace pyrite, pyrrhotite, and chalcopyrite. Where the gabbro is phyllitic, it has more chlorite, sericite, and quartz than the non foliated variety.

Rhyolite dikes have several common textures (Johnson and others, 1986), including porphyritic, aphanitic, and granular. The porphyritic variety is most common and includes quartz, quartz and feldspar, and feldspar porphyritic types. The feldspar is commonly albite. The groundmass is aphanitic sericite and quartz. The dikes are locally foliated.

In the Fire Center to Holyoke area (figure 2-4, map plate 1a), pyroclastic rocks include a thin lithic tuff with subrounded to angular lithic fragments of light to medium gray, fine grained foliated quartz - feldspar volcanic rock fragments in a groundmass of aphanitic quartz, sericite, and feldspar.

Two layers of polymictic mudflow breccia and a banded quartz magnetite iron formation strike for 7 km in the east part of the SMLB (A. Carter, R. Johnson, Callahan Mining Corp., personal communication; MacLellan and Bornhorst, 1988). Banded iron formation is laminated quartz - magnetite rock, commonly with chloritic phyllite. A 1 to 3 m thick, fine grained, cherty quartz - chlorite - pyrite - pyrrhotite layer interpreted as a sulfidic cherty exhalite is in the Silver Creek West area in the uppermost exposed part of the basalt (Norby, 1986).

The Granodiorite of Rocking Chair Lakes (GRCL) is a foliated to massive gray to pink, fine to coarse grained intrusion at the northwest boundary of the SMLB. It has 20 - 40% plagioclase, less than 5% K-feldspar, 30 - 40% quartz, 20 - 40% amphibole, and minor sericite and carbonate (Johnson and others, 1986). The GRCL was previously interpreted as a zoned sill, with a volumetrically minor granite core surrounded by a main quartz monzonite zone and rimmed by quartz diorite (Bryan, 1970). Metamorphic grade increases from lower to upper greenschist facies in the surrounding volcanic rocks toward the contact of the GRCL, indicating a metamorphic auerole around the intrusion. Granitoid dikes, sills, and apophyses are abundant along the margins of the GRCL and persist for more than 300 m east of the main intrusion (Gleason, 1985). Black - colored basalt along the west contact of the GRCL is mostly amphibole, interpreted as contact metamorphism (Johnson and others, 1986).

Three 100 m diameter granodiorite plugs intrude the upper parts of the SMLB in the Silver Creek West and Fire Center to Holyoke areas (figure 2-8, map plate 1a) . The rock is pink, medium to coarse grained, massive to foliated plagioclase, microcline and quartz.

Foliation in the SMLB is approximately 110° with a near vertical dip and is parallel to or at a slight angle to bedding, whereas rocks of the Lower Proterozoic Michigamme Formation to the south in the Dead River basin have a south dipping cleavage at a high angle to bedding. This suggests that the foliation in SMLB predates the cleavage in the Proterozoic rocks.

There are three main sets of faults in the SMLB (Callahan Mining Corp. detailed mapping; Johnson and others, 1986; MacLellan and Bornhorst, 1988): (1) An older set parallel to the trend of foliation, marked by up to 30 m wide zones of pronounced foliation and secondary carbonate - sericite in basalt, (2) a younger north striking set of faults marked by up to 15 m wide foliated zones and topographic ravines which offset the northwest trend of the Archean rocks as well as the older faults, and (3) east striking faults brecciated and occupied by east striking Keweenawan dikes in the Fire Center to Holyoke area (Owens and Bornhorst, 1985).

Boundaries of the SMLB include a transition to amphibolite along parts of the far northwest boundary of the block, intruded by the Granodiorite of Rocking Chair Lakes. The Early Proterozoic Clark Creek basin bounds the central part of the block's north side. East of the Clark Creek basin a metamorphic gradient marks the boundary between the SMLB and the North block. Grain size of the granoblastic amphibolite in the North block decreases from northeast to southwest toward the SMLB and is less hornblendic and more acicular. This boundary is complicated by intrusion of diabase dikes (Bouley and Hodder, 1987).

The Dead River shear zone (DRSZ) is the south boundary of the SMLB. Mapping and some drilling indicates that the DRSZ only locally coincides with the present day topographic range front which marks the boundary between the Archean high ground of the SMLB on the north and slate of the Lower Proterozoic Michigamme Formation on the south (figure 2-4). South of the Silver Creek prospect, for example, the contact between Archean and Proterozoic rocks is marked by a dipping surface with a several centimeter thick quartz vein at the contact, rather than by a major shear zone.

2.3.1.6 The North Block

Most rocks in the North block are layered to massive amphibolite of epidote amphibolite facies (Gair and Thaden, 1968). The distinction between greenschist and epidote amphibolite facies is made on the basis of a plagioclase anorthite content greater than 10%. Layered amphibolite is dark green, well foliated rock with tabular layers 3 to 8 cm thick and 3 to 10 m long separated by centimeter thick darker green bands. These elongate lenses may be stretched pillows. Pillows with a 5:1 length to width ratio are in Section 32, T49N, R26 W (Bouley and Hodder, 1987). Alternately, if the protolith is basalt tuff, the lenses may be primary tabular layers of mafic volcanic ash (Gair and Thaden, 1968). The rock is 65 to 85% hornblende as 0.2 to 1.0 mm prisms, which are preferentially aligned parallel to mesoscopic layering. The remaining 15 to 35% of the rock is a variable assemblage of An 30 to 38 plagioclase, quartz, epidote, and carbonate which forms a groundmass for well aligned hornblende. Biotite is locally abundant, with accessory magnetite, sulfide minerals, sphene, and leucoxene (Gair and Thaden, 1968).

Fine to coarse grained massive amphibolite is anhedral dark green hornblende to pale green actinolitic hornblende as ragged prisms probably centered on former mafic minerals, with very saussurite or sericite rich plagioclase in the interstices. Biotite and quartz are minor with accessory ilmenite and magnetite. Biotite is pseudomorphed by chlorite. Parts of the coarse grained amphibolite may be metamorphosed gabbro sills and dikes, although some may be recrystallized basalt (Bouley and Hodder, 1987).

Minor parts of the North block are massive to pillowed aphanitic basalt, with a foliated groundmass of hornblende, sodic plagioclase, epidote, and aligned aggregates of epidote, sericite, and chlorite. This rock is best exposed in Sections 18 and 7, T48N, R25W, where a lense up to 300 m thick is between amphibolite and the Nealy Creek Member of the Mona block. Smaller tabular bodies of basalt are within layered amphibolite near Lighthouse Point in Marquette, east of the primary occurrence described above (Gair and Thaden, 1968).

Felsite, probably originally rhyolite, is minor in the North Block, and is pale green - gray, fissile to flinty, fine grained quartz - sericite rock with granoblastic mosaics of quartz, sericite flakes, and minor feldspar and chlorite (Gair and Thaden, 1968). Locally, tourmaline is in felsite at Lighthouse Point (ibid.).

Granite dikes up to 10 m thick cut both the Compeau Creek Gneiss and the Grandiorite of Rocking Chair Lakes. Unfoliated diorite stocks several 100 m in diameter intrude the amphibolite. Quartz veins cut the granite dikes but not the diorite stocks (Small and Bornhorst, 1989). Coarse grained pink to brick red pegmatite with alkali feldspar is exposed along the east trending scarp in amphibolite at the north side of Clark Creek basin at the junction with north trending ravines. It is potassic granite filling faults, but its age and relationship to amphibolite is not known (Bouley and Hodder, 1987).

The north boundary of the North block with the Compeau Creek Gneiss is a kilometer wide zone of interlayered gneiss, migmatite, and amphibolite. This transitional contact may indicate assimilation and metamorphism of basalt to amphibolite by intrusion of tonalite of the Compeau Creek Gneiss. A 200 to 300 m wide zone of felsic augen with saussuritized feldspar porphyroblasts is within the amphibolite, 200 to 1000 m away from the contact with the Compeau Creek Gneiss in the Negaunee Quadrangle (Puffett, 1974). This is interpreted as glomerophyric basalt with a well developed flattening fabric, metamorphosed to amphibolite facies (Johnson, R. C., personal communication, 1989). The southwest boundary of the North block is the Willow Creek shear zone (WCSZ) (Puffett, 1974). Further to the southeast the WCSZ does not strictly follow the boundary between amphibolite facies rocks of the North block and greenschist facies rocks of the Silver Mine Lakes block, and it is largely obscured by diabase and gabbro dikes localized along the boundary (Bouley and Hodder, 1987). There is, however, a gradual increase from greenschist to amphibolite facies from south to north across the North block, north of the Clark Creek basin (Small and Bornhorst, 1989), with the southernmost part of the block generally at greenschist facies.

The Silver Lake area, included here in the North block, is interpreted as a northwest outlier of the Marquette greenstone belt. The Silver Lake area is a syncline striking 335°, cored by biotite - muscovite - garnet schist with a probable fine grained pelitic sedimentary rock protolith, and rimmed successively by hornblende - chlorite schist with a probable basalt protolith, and granite gneiss. Foliation in the gneiss parallels that in the biotite - muscovite - garnet schist and hornblende - chlorite schist and is conformable with the inferred axis of the syncline. Diabase dikes and sills cut the hornblende - chlorite schist but not the biotite - muscovite - garnet schist. Minor quartz - porphyritic rhyolite dikes and a serpentine rich basic dike cut the section, and minor barren quartz veins range in strike from east to northeast (Zinn, 1936).

Known metallic mineral occurrences are sparse in the North block; there is no recorded metal production, and quartz veins in amphibolite are sparse, narrow, and generally barren (Bouley and Hodder, 1987).

Only the southwest and north central parts of the North block have been mapped (Johnson and others, 1986; Small and Bornhorst, 1989). A synformal anticline with a fold wave length of several km is mapped in the Rocking Chair Lakes area at the west end of the North block, based on the interpretation that two separate occurences of mud flow breccia are fold limbs of the same unit, and that similarly configured gabbro is a folded sill (Johnson and others, 1986). A southeast plunging synform in the Negaunee Quadrangle is inferred from foliation attitudes in layered amphibolite between Reany Creek Formation to the south and Compeau Creek Gneiss to the north (Gair and Thaden, 1968). Rhyolite dikes cut the foliation in layered amphibolite.

2.3.1.7 Reany Creek Block

The Reany Creek Formation is possibly of Archean age, based upon its spatial association with Archean rocks, its similar metamorphic grade relative to the known Archean rocks, and its structural and lithologic similarity to Timiskaming type conglomerates of the Abitibi subprovince (Thurston and Chivers, in press). It is an east trending steeply south dipping belt 1.5 km wide which overlies volcanic rocks in the Silver Mine Lakes block with angular unconformity, and has three parts (Puffett, 1969): 1.) a basal part is conglomeratic, 60 to 750 m thick, with rounded to angular boulders of basalt, banded pyritic iron formation, granite, granodiorite, rhyolite, and basaltic slate in a subordinate poorly sorted coarse grained arkose matrix with angular feldspar, quartz grains, rock fragments, and chlorite after mafic minerals. 2.) A middle part is thinly foliated olive green slate with angular feldspar and round to angular quartz in a chlorite - sericite matrix, with widely dispersed granite cobbles; graywacke, with plagioclase, microcline, quartz, chlorite, and quartz - feldspar rock and basalt fragments; and well sorted arkose with 2:1 feldspar to quartz. 3.) An upper part is meter scale interbedded arkose, chloritic slate, graywacke, and conglomerate with 5 to 10 cm granite clasts and well developed Bouma sequences. The upper part is in apparent fault contact with rocks of the Sheared Rhyolite Tuff and Nealy Creek members of the Mona block.

The Reany Creek Formation may be Early Proterozoic age based on: 1) its unconformable contacts with the underlying Archean volcanic rocks of the Silver Mine Lakes block, 2) dispersed granite clasts which may be glacial dropstones, and 3) its chemical similarity to the Proterozoic Gowganda Tillite in Ontario, in terms of its high Na_2O: K_2O, low CaO, and FeO: Fe_2O_3, which are distinctly different from average Archean slate (Puffet, 1969).

Alternately, at least the basal conglomerate may be Archean, because thin distorted iron formation within it has vertically plunging folds consistent with those locally observed in Archean rather than Proterozoic rocks (Owens and Bornhorst, 1985). Two small tabular rhyolite bodies, possibly Archean rhyolite dikes equivalent to those in the Silver Mine Lakes block, cut bedding within conglomerate at an oblique angle. Conglomerate may have filled a graben which was truncated as a result of Archean faulting along the Dead River shear zone (Weeks, 1987). The Reany Creek Formation may be a mass flow deposit similar to Archean Timiskaming sediments of Ontario (Engel, 1954; Mattson and Cambray, 1983). Arkose, graywacke, and chloritic slate of the Reany Creek Formation underlie Michigamme Formation black slate with angular uncomformity in Section 1, T48N, R27W. Observed age relations indicate the Reany Creek Formation post dates Archean volcanic rocks but pre dates Lower Proterozoic Michigamme Formation.

2.3.1.8 Dead River Pluton

The Dead River Pluton (DRP) intrudes the Nealy Creek Member of the Mona Block and has apophyses into the Nealy Creek Member. There is a hornfels contact aureole within the Nealy Creek Member adjacent to the pluton. The DRP is a nonfoliated, commonly porphyritic, composite intrusion with three compositional facies; granodiorite, diorite, and syenite (Puffett, 1974): 1) Porphyritic granodiorite is coarse poikilitic tabular pink microcline feldspar phenocrysts in a hypidiomorphic granular groundmass of andesine, orthoclase, microcline, quartz, hornblende, biotite, and chlorite with accessory apatite and ilmenite and secondary sericite, carbonate, and leucoxene. This is the most voluminous rock type. It is a possible intrusive equivalent of dacite and andesite tuff and volcanic conglomerates of the Kitchi block (Hagni, 1954). 2) Hornblende diorite is an equigranular rock of plagioclase and subhedral hornblendic amphibole, with irregular aggregates of biotite, chlorite and microcline. 3) Coarse porphyritic syenite is in northwest trending zones within the pluton, and is abundant 0.5 to 5 cm gray to pink perthite in a subordinate dark groundmass of hornblende, biotite, feldspar, sphene and magnetite.

Age relations between facies are not known. The DRP pre dates Reany Creek Formation, based on petrologic similarities of the DRP to several small igneous bodies to the north in the Silver Mine Lakes block which are truncated by the base of the Reany Creek Formation (Puffett, 1974).

2.3.2 Structure

2.3.2.1 Structures Bounding Blocks of the Marquette Greenstone Belt

Major structures are the Carp River Falls, Carp River, Peridotite, Dead River and Willow Creek shear zones (figure 2-4). The Carp River Falls shear zone (CRFSZ) is an east striking nearly vertical zone of phyllonitic, carbonate - sericite rich rock south of the Marquette greenstone belt. It separates Late Archean from Lower Proterozoic rocks for most of its length, but strikes through foliated basalt, probably of Archean age, in Negaunee Township.

The Carp River shear zone (CRSZ) is postulated to follow the valley of the Carp River between the Kitchi block and the Mona block, on the basis of the topographic low defined by the valley, the presence of well foliated rocks marginal to the valley, and because facing directions are southeast, south of the CRSZ and north, north of the CRSZ.

The Peridotite shear zone strikes along the northwest margin of the Deer Lake Peridotite. It may have originated as a hinge line which controlled distribution of contrasting basalt and dacite facies, localized banded iron formation and greywackes along the southeast side of the Bjork - Lundeen block, and later controlled intrusion of the Deer Lake Peridotite.

The Dead River shear zone (DRSZ) is a zone of phyllonitic, carbonate and quartz rich rock which generally parallels the south margin of the Silver Mine Lakes block, separating it from Early

Proterozoic Michigamme Slate. Extensive areas of secondary carbonate and sericite are in basalt north of the DRSZ in the Silver Creek West and Silver Creek areas.

The Willow Creek shear zone (WCSZ) is well foliated basalt and partly is the boundary between greenschist facies rocks to the south and amphibolite facies rocks to the north. The continuation of the WCSZ east of the wedge of the Reany Creek Formation is a sharp boundary between amphibolite of the North block and greenschist facies rocks of the Sheared Rhyolite Tuff and Nealy Creek members of the Mona block.

Lower Proterozoic sedimentary rocks structurally abut Archean rocks along the north side of the Marquette trough along the CRFSZ and also along the north side of the Dead River basin along parts of the DRSZ, whereas they overlie Archean rocks in possible depositional unconformity along the south side of the Dead River basin and the Clark Creek basin, consistent with steep north sides and shallower south sides in these Early Proterozoic basins. Faulted and sheared contacts between rocks of the Marquette Supergroup and Archean rocks along the CRFSZ and DRSZ indicate Proterozoic age movement on these structures (Cambray, 1984; Carter, P., 1988). Lower Proterozoic rocks range from virtually undeformed to mylonitic within the Marquette trough, implying that discrete shear zones controlled Early Proterozoic deformation in the Marquette trough, as opposed to widespread ductile deformation further west near Republic (Longiaru, 1989).

The shear zones were also Archean features which acted as conduits for hydrothermal fluids throughout development and structural modification of the volcanic terrane. Most gold prospects in the Marquette greenstone belt are within several hundred meters of these structures. Rocks cannot be correlated across zones of high strain separating blocks of the Marquette greenstone belt. Because Lower Proterozoic rocks of the Marquette Supergroup are deformed on the same structures which bound the blocks, there was some component of Early Proterozoic or younger tectonism.

2.3.2.2 Structures within Blocks

Compilation of topograpnic lineament directions in the Marquette greenstone belt using 1:10,000 aerial photographs

(Lehnertz, 1987) indicate a number of prominent orientations which correlate with mapped faults, auriferous quartz veins, and bedding (figure 2-9). Parts of the Bjork - Lundeen block, Deer Lake Peridotite, and Kitchi block are considered herein (figure 2-10): 1). A prominent northeast set is most common within the Deer Lake Peridotite and along its margins and corresponds with the strike of the DLP contacts and the strike of zones of foliated serpentinite within the DLP. 2). A persistent east to southeast set coincides with the orientation of some major quartz veins, as at the Bjork - Lundeen prospect. 3). An east northeast set is most common within the Bjork - Lundeen block west of the Deer Lake Peridotite, and within the wedge of Ajibik Quartzite southeast of the Peridotite where it is the orientation of bedding or layering of rock types. and 4). A steep north northeast set is present throughout the area. Minor faults with dextral offset occur along this orientation, for example, in the Ropes deposit and along the margins of the Deer Lake Peridotite (DLP). This fault direction was active in post Early Proterozoic time because it offsets contacts of the Lower Proterozoic Ajibik Quartzite south of the DLP (map plate 2).

Figure 2-9. Interpreted major lineament directions in the Northern complex, depicting dominant northeast, east southeast, and east trends.

Directions illustrated here are recognized from the alignments of thousands of minor lineaments compiled from aerial photographs. This diagram merely illustrates the major features which are reflected by zones of greatest abundance of minor lineaments (summarized from Lehnertz, 1987).

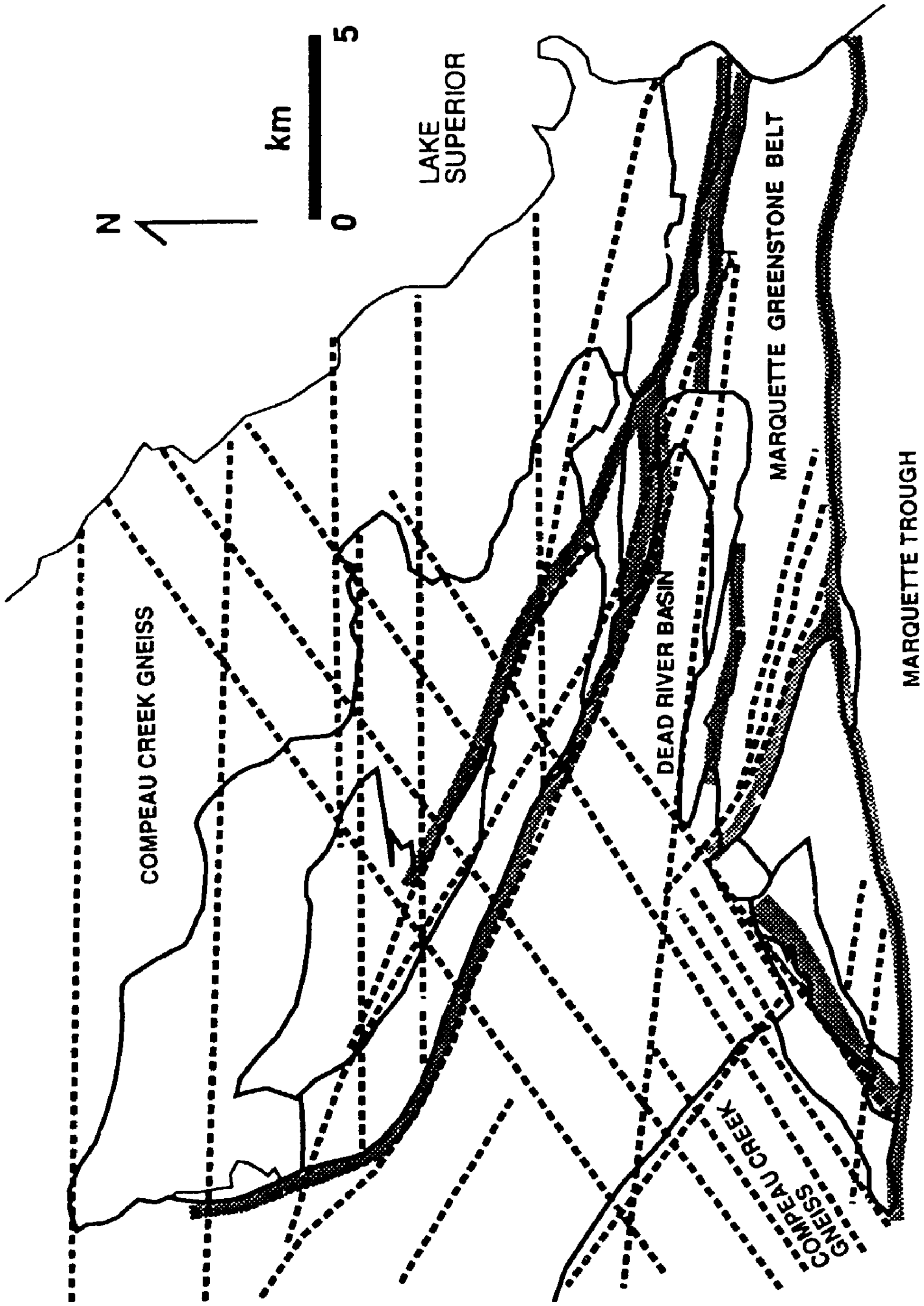

N
0
km
5
LAKE
SUPERIOR
COMPEAU CREEK GNEISS
DEAD RIVER BASIN
MARQUETTE GREENSTONE BELT
MARQUETTE TROUGH
COMPEAU CREEK
GNEISS

Figure 2-10. Prominent lineaments in part of the Marquette greenstone belt surrounding the Ropes deposit, depicting dominant northeast, east southeast, east to east northeast, and north northeast trends. Lineaments were originally compiled from approximately 1:10,000 scale aerial photographs and transferred to topographic map base (summarized from Lehnertz, 1987).

paved road

unimproved roads

contour interval 6 m


N
0
km
1
Ropes mine
1400
1500

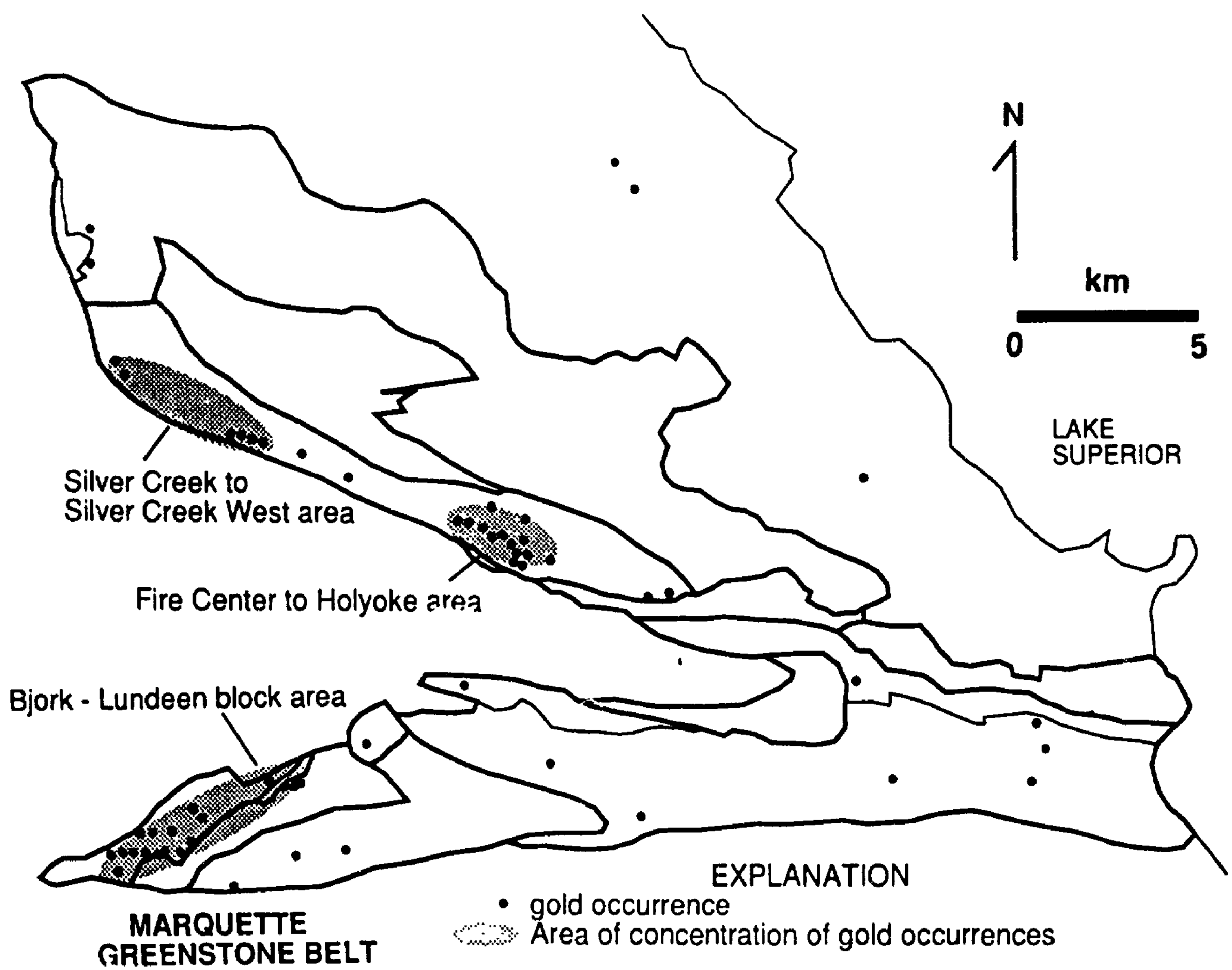
2.3.3 Distribution of Gold Concentrations

Gold is widely distributed in the Marquette greenstone belt, but is concentrated in three main areas, one within the Bjork - Lundeen block and the second and third within the Silver Mine Lakes block:

1) A kilometer wide zone with gold occurrences is within the Bjork - Lundeen block along the north side of the Deer Lake Peridotite from the Ropes mine to the Michigan mine (figure 2-11). Only the Ropes deposit and the Michigan deposit have had production (table 1-1). The Peninsula and Bjork - Lundeen prospects have modest drill indicated gold resources (table 1-1).

The Bjork - Lundeen prospect is a 1 to 3 m wide, 450 m long gold bearing trend of pyritic quartz veins which strike west northwest perpendicular to a flexure in the northeast trending volcanic rocks (map plate 2). Minerals with gold within the quartz vein are red, Fe bearing potassium feldspar, calcite, tourmaline, and chlorite. Thin foliated zones of wall rock contain calcite, chlorite, quartz, pyrite, and tourmaline. Offsets of minor veins which cut across the zone, and S - C' fabrics defined by microlithons indicate

Figure 2-11. Areas of concentration of gold occurrences in the Marquette greenstone belt.


N
km
0
5
LAKE
SUPERIOR
Silver Creek to
Silver Creek West area
Fire Center to Holyoke area
Bjork - Lundeen block area
MARQUETTE
GREENSTONE BELT
EXPLANATION
gold occurrence
Area of concentration of gold occurrences

right lateral, north side up movement along the trend, but locally an earlier ductile foliation at the margins of the shear zone indicates a sinistral sense of movement.

The Peninsula prospect is two en echalon zones of gold concentration, each approximately 5 meters wide, 30 meters long, and 50 meters in dip extent (Carter, 1989), which strike north northeast, dip steeply southeast, and are nearly conformable to local rock type layering as defined by the intrusive contact of a granodiorite plug, porphyritic dacite sills, basalts and possible dacite tuffs. Gold content correlates with late fracture controlled ferroan dolomite and also with abundance of quartz veinlets. Biotite is partly replaced by chlorite within ore zones. The north zone is within siliceous dacite tuff, whereas the south zone is within pillowed basalt. The zones of gold concentration are near the east and southeast margins of a granodiorite plug.

The Michigan gold deposit is within one of several parallel, east striking, steeply south dipping quartz veins in basalt along the margin of a similarly striking large gabbro dike. The 1 to 2 m wide quartz vein has no altered margins and contains accessory tremolite, calcite, pyrite, pyrrhotite, molybdenite, and scheelite. Concentrations of gold in the quartz vein are in 1 m wide by 10 m long shoots with a vertical dimension of 20 meters along a near vertical plunge. There are additional minor gold occurrences with quartz veins along an easterly trend from the Michigan mine (figure 2-12).

2) The Silver Creek to Silver Creek West area (figures 2-11, 2-13) is in the south part of the west end of the Silver Mine Lakes block (figure 2-4). Gold concentrations at the Silver Creek West prospect are in an east southeast striking zone of chlorite - sericite - ferroan dolomite with dispersed pyrite, in sheared basalt with pervasive S - C' fabric, and in fractures and veinlets. This gold concentration is within a broader kilometer long zone of basalt with ferroan dolomite as replacement and fracture fillings (map plate 1a). Porphyritic rhyolite sills intrude the basalt at the south side of the gold concentration and are themselves sericite - altered (Norby, 1988b).

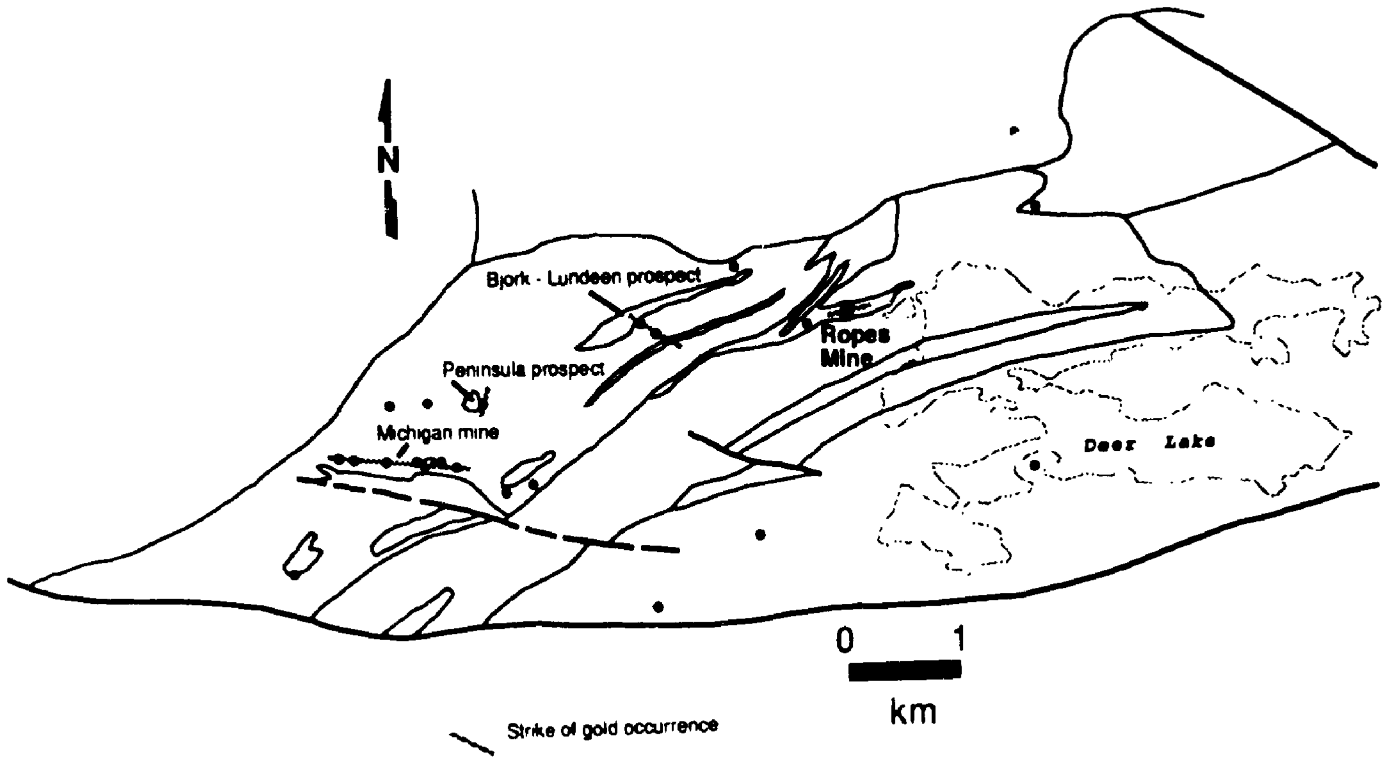
Gold concentration at the Silver Creek prospect (figure 2-4) is with brecciated zones within and along the margins of a feldspar -

quartz porphyritic rhyolite branching sill with marginal breccias of angular fragments which are healed by quartz - albite - ferroan dolomite - pyrite extensional veinlets, and cut by later chlorite folia with tourmaline. Gold concentration is coincident with abundance of ferroan dolomite and pyrite in fractures (Brozdowski, 1989b).

3). The Fire Center prospect to Holyoke mine area is in the south and central parts of the east end of the Silver Mine Lakes block (figures 2-4, 2-11). Gold concentrations are along sheared and pyritic margins of large rhyolite sills near the Fire Center prospect; and at the Holyoke mine in quartz veins, and in basalt replaced by ferroan dolomite (Carter, 1988a).

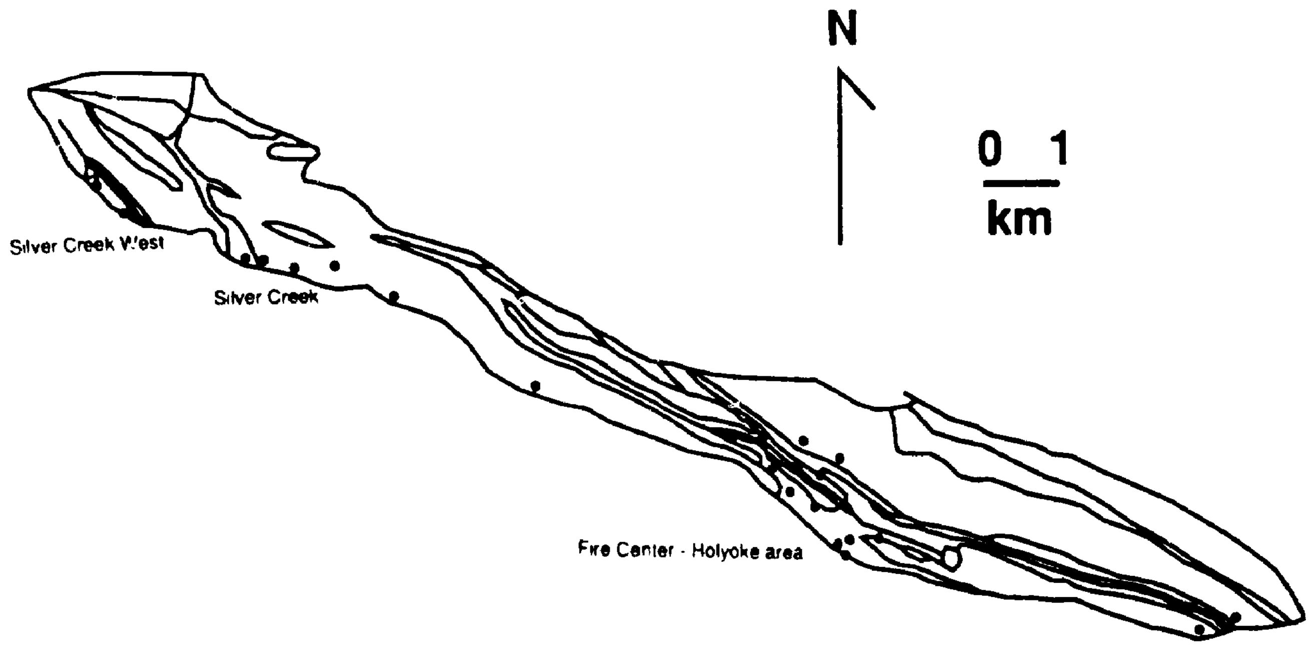
Several gold concentrations are in the upper part of the Lower Member of the Mona block, as at the Pine Hill prospect (figure 2-4) where gold is in quartz veins up to 20 cm thick within carbonaceous interflow sedimentary rock, in fractures in gabbro sills, and with pyrite - carbonate rich zones within basalt. Gold concentrations up to 2 g/tonne are also in a 20 cm thick, tabular, graphite - pyrite rich zone which is parallel to foliation, accompanied by conglomerate with quartz and framboidal pyrite clasts, within

Figure 2-12. Gold occurrences in the southwest part of the Marquette greenstone belt.



• Gold occurrences in the southwest part of the Marquette Greenstone Belt

Figure 2-13. Gold occurrences in the Silver Mine Lakes block.



• Gold occurrences in the Silver Mine Lakes block sericite slate at the contact of the Lower Member with the Nealy Creek Member at the Marquette Mall prospect (figure 2-4). Secondary seams and veinlets of quartz and carbonate are partly occupied by hematite. The nearby Eureka Iron Prospect, at 1188 m N - 915 m E from the SW corner Section 21, T48N, R25W, was developed on a similar earthy hematite concentration (Gair and Thaden, 1968). The pyrite - graphite rich zone can be traced in outcrop and angular float at least 1000 m west along the contact, and inferred further west as a VLF - EM conductor.

Most of the concentrations of base and precious metals in the Precambrian of northern Michigan, exclusive of native copper, are in the Marquette greenstone belt. A few gold concentrations are in Lower Proterozoic rocks outside the Marquette greenstone belt, such as the gold in a northeast trending near vertical meter wide layered quartz - chlorite vein with tourmaline at the Ten Kilns Prospect northeast of the Ropes gold deposit (map plate 2). At the Champion iron mine 27 miles west of Ishpeming, Michigan, gold is in rock mapped as Negaunee Iron Formation: 1.) with abundant tourmaline and minor pyrite and chalcopyrite in specular hematite ore (8.4 g/tonne over 1 core m), 2.) in quartz - carbonate filled fractures in a possibly discordant magnetite body footwall to the Champion orebody, 3.) in a rhodonite tension veinlet where gold is with Mn bearing garnet (Babcock, 1966; Owen, 1983), and 4.) with greisen - like andalusite - chloritoid - ilmenite rock with coarse grained, radiating undeformed muscovite, hematite, chlorite and molybdenite.

CHAPTER 3 GEOLOGY OF THE ROPES GOLD DEPOSIT

3.1 General Statement

Rocks in the southwest part of the Marquette greenstone belt in general have mineral assemblages of the lower greenschist facies and well preserved primary textures and fabrics. However, in the Ropes deposit there are hydrothermally altered and structurally deformed rocks, which are described herein by their dominant mineral assemblages, listed in decreasing order of abundance, such as "quartz - sericite - chlorite rock". Their interpreted protoliths are named from relict textures and from trace element abundances in whole rock.

The southwest part of the greenstone belt (figure 2-7, map plate 2) is, from west to east: 1.) Pillowed and massive basalt intruded by hypabyssal gabbro, with an interlayered transition to dacite tuff and subordinate tuff breccia. These comprise the Bjork - Lundeen block; 2). Serpentinitic, fine grained peridotite of the Deer Lake Peridotite, which is carbonate - talc rock in proximity to the

Ropes deposit; and 3). Dacite tuff breccia and tuff of the Kitchi block. Volcanic rocks strike northeast, with a bend east northeast at the Bjork - Lundeen gold occurrence, 1.5 km west of the Ropes deposit (map plate 2). Rocks face consistently to the southeast, based on pillow shapes and graded bedding.

The Ropes deposit is southeast of the transition from dominantly basalt to the northwest to dominantly dacite tuff to the southeast (figure 3-1, map plate 2). Meter thick banded iron formation and several meter thick graywacke are within the dacite upsection from the interlayered basalt and dacite (plate 2-3). Quartz and sericite progressively overprint and then ultimately pseudomorph all feldspar phenocrysts in dacite tuff as the Ropes gold deposit is approached from the west; the deposit is in this quartz - sericite - chlorite rock which is interpreted as quartz - sericite altered dacite tuff (plate 3-1, 3-2a,b).

The four major rock types in or immediately bounding the Ropes deposit (figures 3-1, 3-2, 3-3; map plate 3) are: 1.) Fine grained quartz - sericite - chlorite rock encloses ore, strikes 070° overall, but 080° where it hosts the Ropes deposit, and dips steeply south (plates 3-1c, d; 3-2). This rock type is bounded to the north and south by, 2.) fine grained, carbonate - quartz - chlorite rock (plates 3-6a, b; 3-7, 3-8) which is massive to compositionally layered on a scale of several millimeters. It and the quartz - sericite - chlorite rock are locally complexly interlayered, particularly in the west part of the deposit (map plate 4) and have generally sharp contacts. Carbonate - quartz - chlorite rock is flanked successively, on both the north and south sides by, 3.) fine grained, massive to moderately foliated, carbonate - talc rock (plate 3-10c, d; 3-11), and 4.) fine grained, serpentinitic peridotite which commonly has relict cumulate texture after original olivine (plate 3-10a) and lesser pyroxene. This is variably carbonate - bearing near its contacts with carbonate - talc rock (plate 3-10b). Contacts between carbonate - quartz - chlorite rock and carbonate - talc rock, and between the carbonate - talc rock and serpentinitic peridotite are generally gradational over one to several meters.

Sericite in relict feldspar and lithic clasts in the quartz - sericite - chlorite rock decreases gradationally westward from the Ropes main ore zone (plates 3-1, 3-2a to c) over a distance of several hundred meters into a large body of dacite tuff that has moderately aligned twinned plagioclase phenocrysts, with only very minor sericite internal to the phenocrysts, bipyramidal quartz, and volcanic rock fragments in an aphanitic quartz - sericite - feldspar - chlorite matrix. The dacite tuff has local lapilli - sized fragments as well as tuff breccia layers (plate 2-3d).

Carbonate - quartz - chlorite rock is restricted largely to the immediate periphery of the deposit (figure 3-1; map plate 3), although layers up to 2 m thick occur up to 400 m west of the Ropes main ore zone. The thickest layers of carbonate - talc rock are immediately north and south of the deposit (figure 3-1); however, there are thin layers of talc - rich rock at numerous localities at the contacts of, and also within serpentinitic peridotite along the northwest contact of the peridotite up to 500 away from the deposit. Serpentinitic peridotite is up to 2 km northeast of the Ropes deposit and up to 5 km southwest of the deposit in a northeast trending outcrop pattern approximately 600 m wide (map plate 2).

Figure 3-1. Geologic map of the Ropes gold deposit

EXPLANATION

Proterozoic

11. Graywacke
10. Quartzite

Archean

9. Serpentinitic peridotite
8. Carbonatate rich serpentinitic peridotite
7. Carbonate - talc rock
6. Compositionally layered to massive carbonate - quartz - chlorite rock
5. Dacite tuff, tuff breccia, and flows; (altered to quartz - sericite - chlorite rock in Ropes deposit
4. Banded quartz - magnetite iron formation
3. Graywacke and siltstone
2. Fine grained gabbro
1. Basalt (includes pillowed and glomerophyric varieties)


Updip Projection to Surface of Orebodies

A = main ore zone
B = northwest ore zone

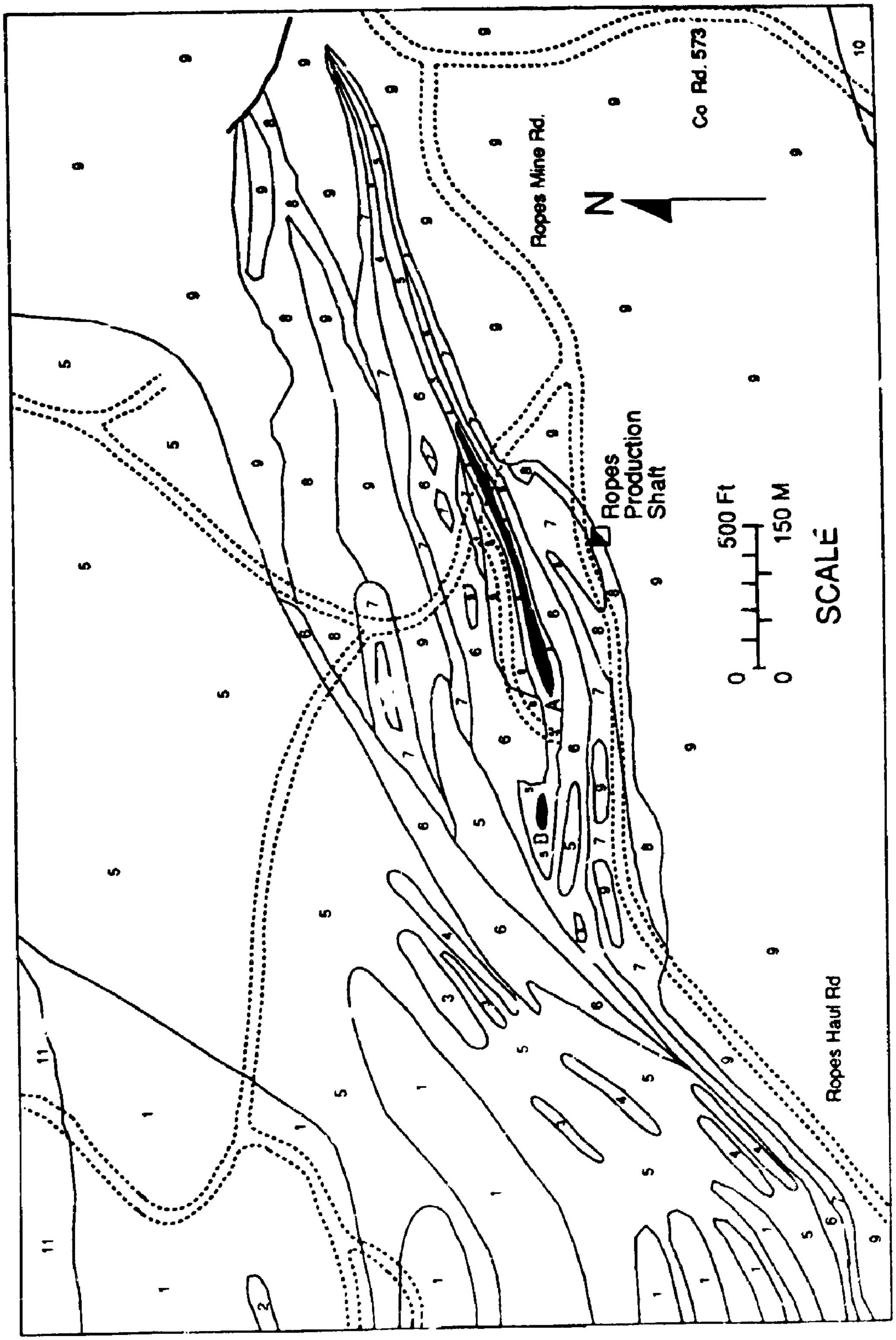

Ropes Mine Rd.
Co Rd. 573
N
Ropes Production Shaft
0
500 Ft
0
150 M
SCALE
Ropes Haul Rd

Figure 3-2. Geologic cross section through the Ropes gold deposit at 600 East. Plane of section strikes 350°.

1. Serpentinitic peridotite, locally carbonate rich

2. Carbonate - talc rock

3. Carbonate - quartz - chlorite rock

4. Quartz - sericite - chlorite rock

5. Orebody, outline of >2 g/tonne Au

Δ Mine levels

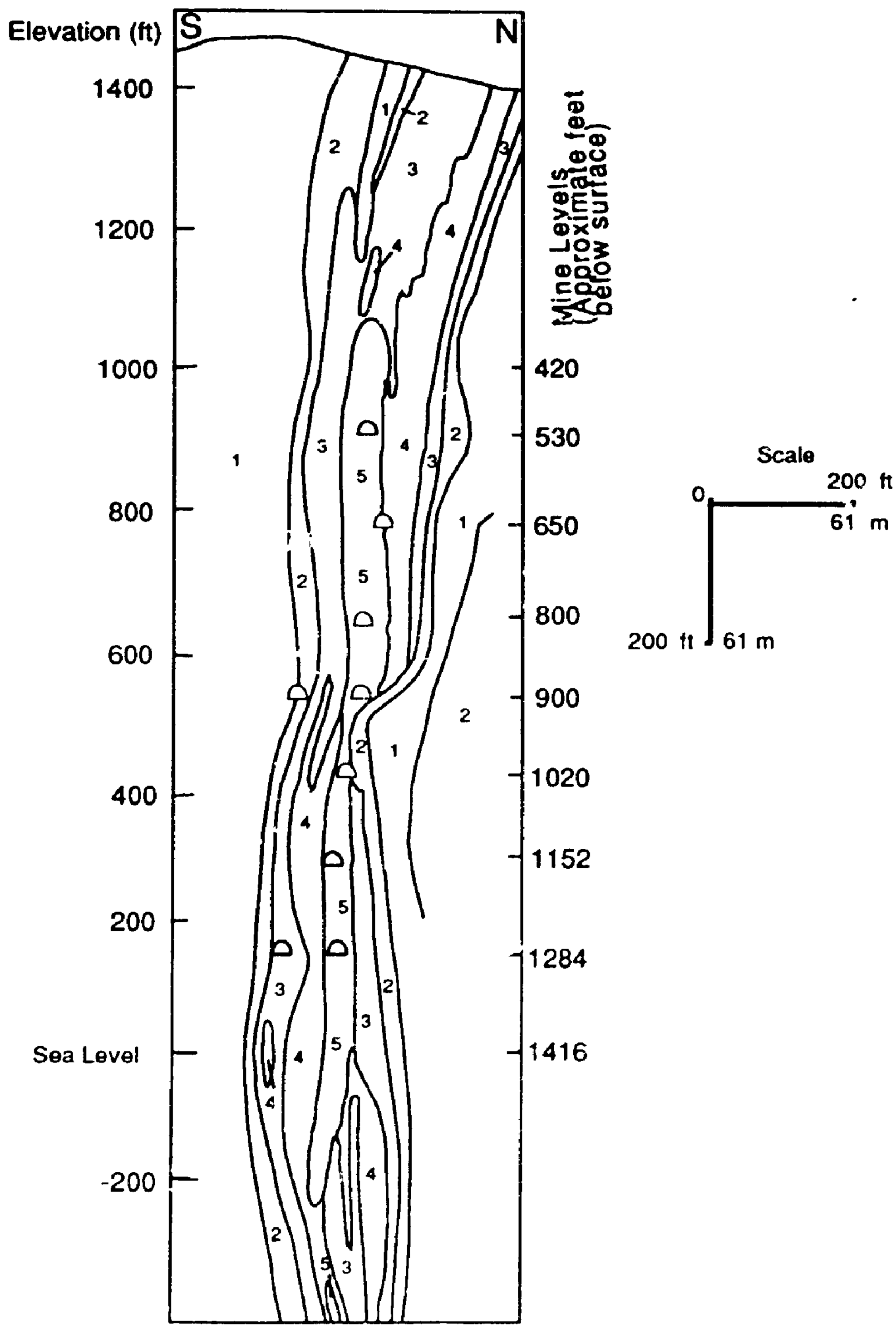

Elevation (ft)
S
N
1400
1200
1000
800
600
400
200
Sea Level
-200
Mine Levels (Approximate feet below surface)
420
530
650
800
900
1020
1152
1284
1416
Scale
0
200 ft
61 m
200 ft
61 m

Figure 3-3. Geologic level plans of the 300 level and 1152 level in the Ropes deposit, illustrating tabular nature of gold concentration on 300 level and en echelon arrangement of gold concentrations on 1152 level. Distances east are in feet, projected from 080° baseline (not shown) which trends along the strike of the quartz - sericite - chlorite rock.

EXPLANATION:

1. Serpentinitic peridotite, locally carbonate rich

2. Carbonate - talc rock

3. Carbonate - quartz - chlorite rock

4. Quartz - sericite - chlorite rock

5. Orebody, outline of > 2 g/tonne Au

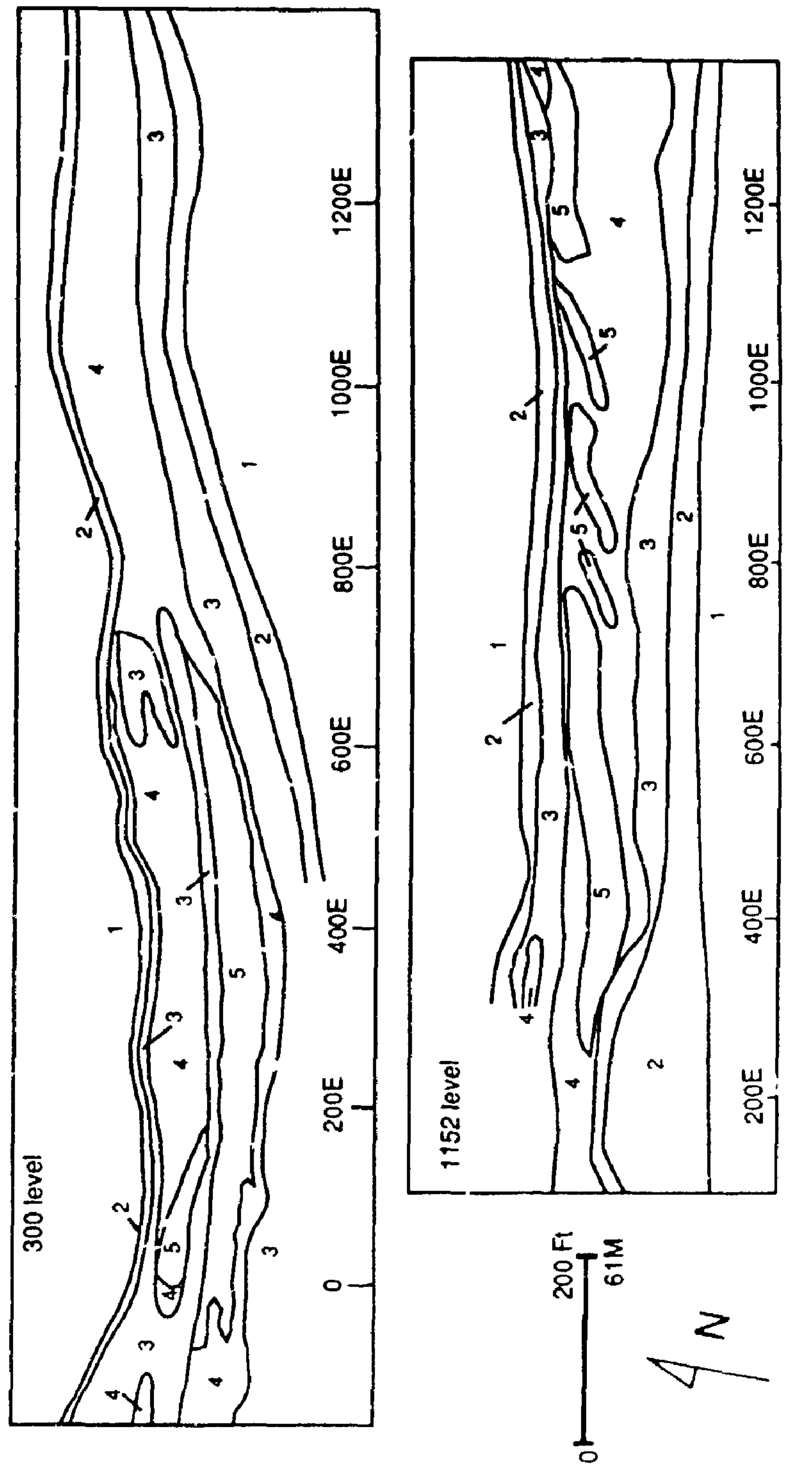

300 level
1152 level
0
200E
400E
600E
800E
1000E
1200E
0
200 Ft
61M
N

Plate 3-1 Progressive sericite alteration and development of planar fabric in dacite tuff of the Ropes deposit. Photomicrographs are 2 mm across in short dimension, photographed in cross polarized light.

A.) plagioclase phenocrysts with minor sericite in aphanitic quartz - feldspar - chlorite - sericite groundmass; from 200 m west of Ropes deposit.

B.) large light colored areas are plagioclase phenocrysts with minor sericite, white areas in matrix are coarser grained secondary quartz; from Ropes decline 50 m west of main ore zone.

C.) sericite pseudomorphic after feldspar phenocrysts, matrix is quartz - sericite - chlorite; from main ore zone.

D.) well foliated quartz - sericite - chlorite rock, former feldspar phenocrysts pseudomorphed by sericite are elongate light colored patches. Dark, round 100 micron sized scattered grains are auriferous pyrite.

A

B

C

D

Plate 3-2. Quartz - sericite - chlorite rocks with variably deformed textures, from Ropes deposit. Photomicrographs are 2 mm across short dimension, photographed in cross polarized light.

A.) Well foliated quartz - sericite - chlorite rock, former feldspar phenocrysts pseudomorphed by sericite are elongate light colored patches, in slightly darker colored quartz - sericite - chlorite matrix, with minor pyrite in upper - center part of photograph.

B.) Irregular patches of light colored sericite with slightly coarser grained quartz (white and gray equant grains) in matrix. Black equant grains are fine grained pyrite. Ropes main ore zone.

C.) Well foliated quartz - sericite - chlorite rock with foliation formed by quartz layers at left and right, and dark chlorite foliation to right of quartz rich foliation on left side of photograph. Fine grained light colored mineral is sericite.

D.) Quartz rich area at upper right, possibly a recrystallized quartz phenocryst, in aphanitic matrix of felted sericite.

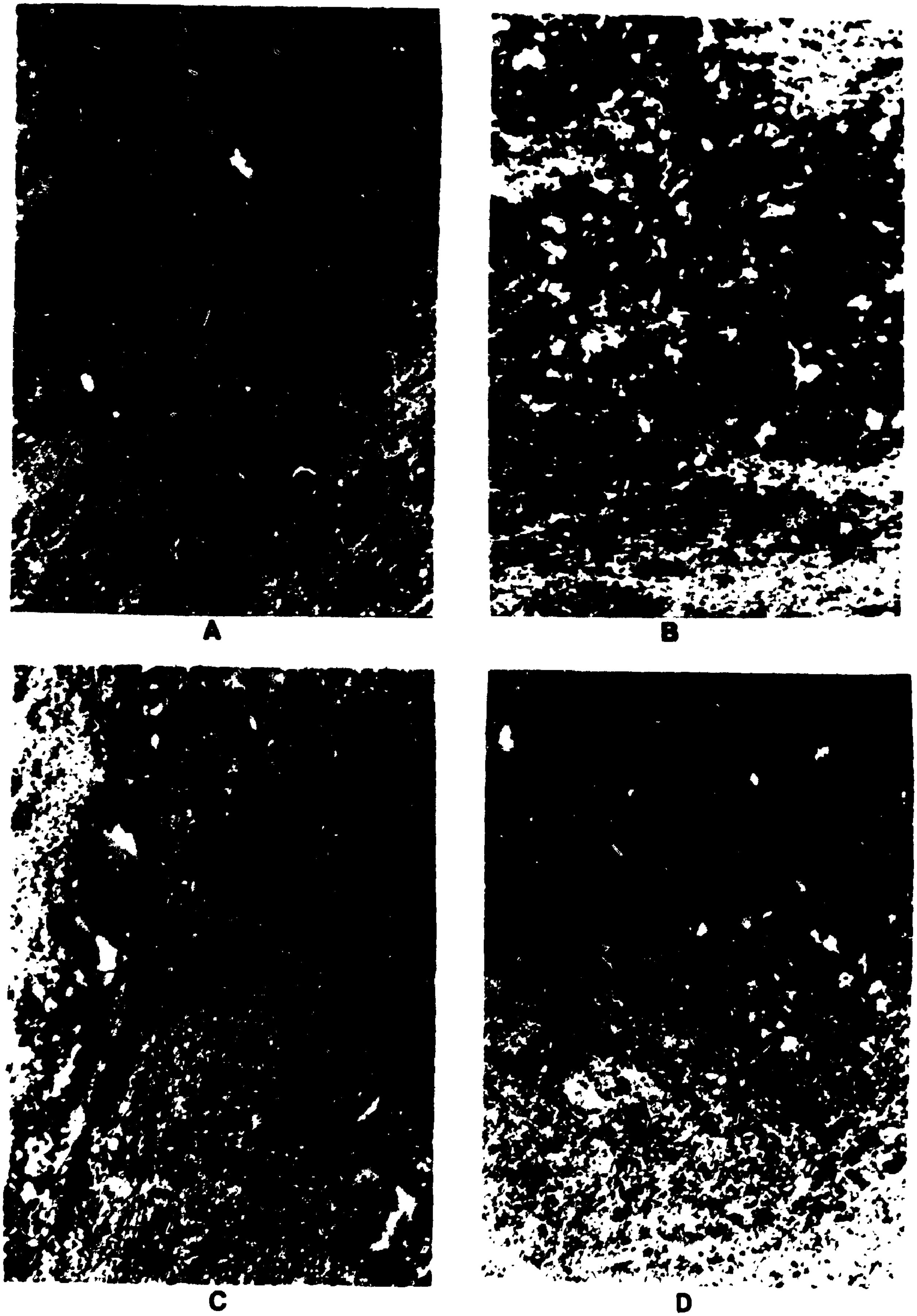

A
B
C
D

Plate 3-3. Rocks from west of Ropes deposit. Photomicrographs are 2 mm across short dimension, photographed in cross - polarized light.

A.) Basalt dike from west end of Ropes deposit, with feldspar phenocryst at lower right, in matrix of feldspar and chlorite.

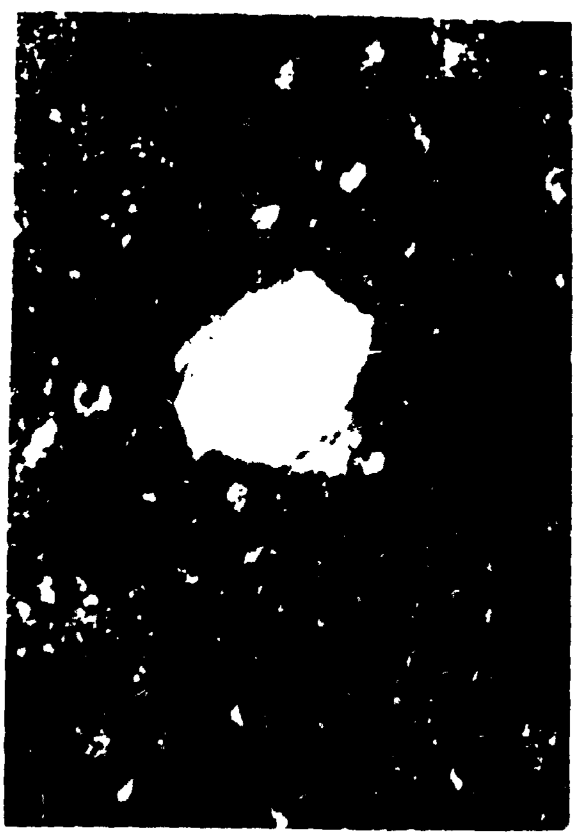
B.) Immature graywacke, with millimeter scale quartz rich laminae and alternating finer grained feldspar - sericite rich laminae.

C.) Dacite tuff with bipyramidal quartz phenocryst, in aphanitic groundmass of feldspar, quartz, sericite and minor chlorite

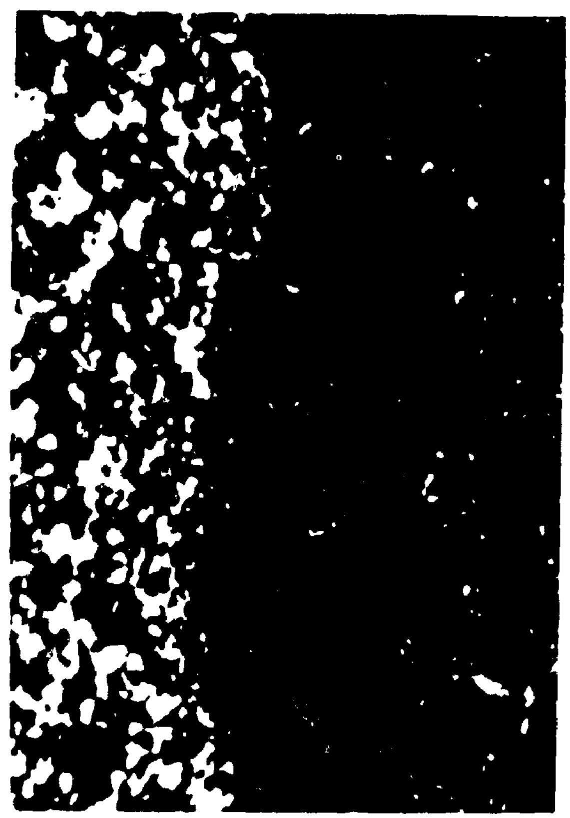
D.) Banded iron formation with (left to right) quartz rich layer, magnetite layer, and chloritic layer.

A

B



C



D

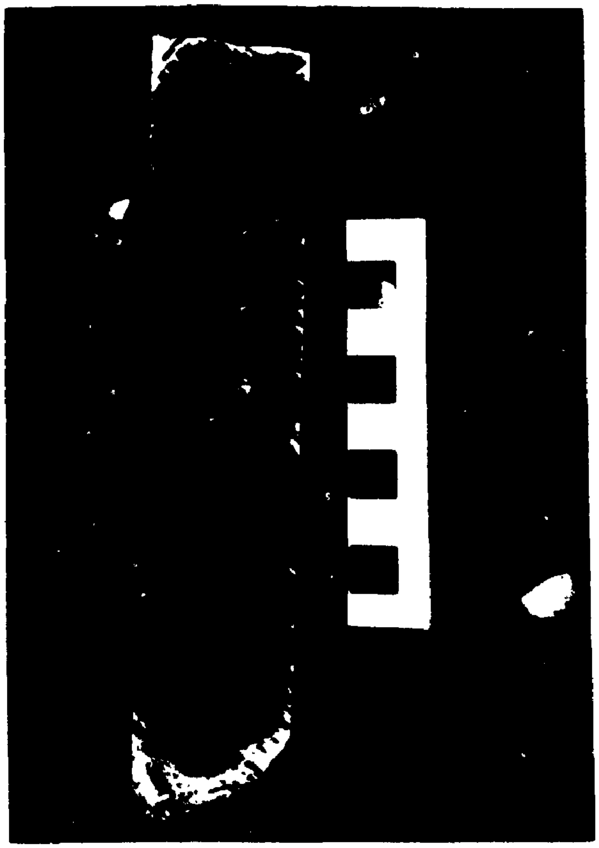
Plate 3-4. Quartz - sericite - chlorite rocks, Ropes deposit. Scale bars are in cm.

A.) Chlorite rich ore (ore subtype 3) with dispersed pyrite in chlorite - quartz - sericite rock, east end of Ropes main ore zone.

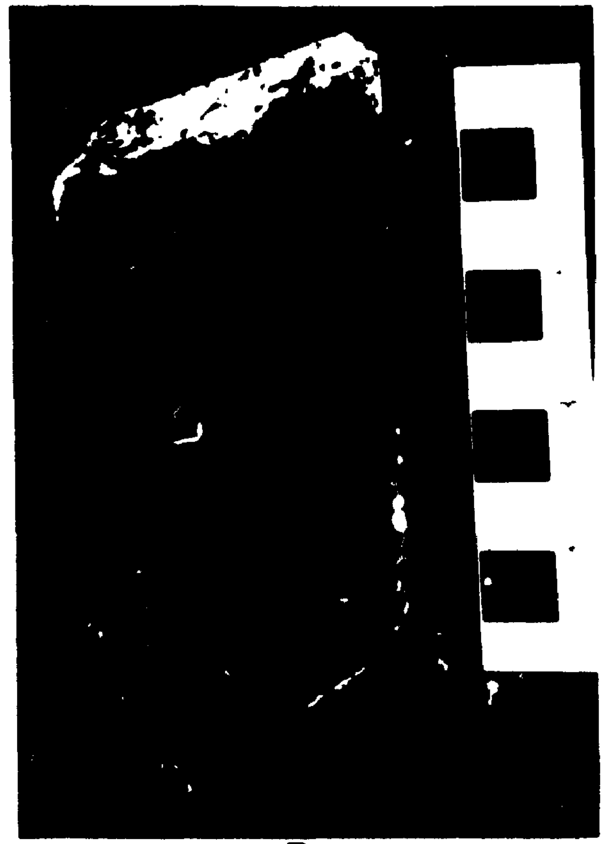
B.) Foliated quartz - sericite - chlorite rock with fine dispersed pyrite (subtype 2), Ropes main ore zone.

C.) Breccia with subrounded fragments of quartz - sericite - chlorite rock in pyritic, chloritic matrix, south side of Ropes deposit.

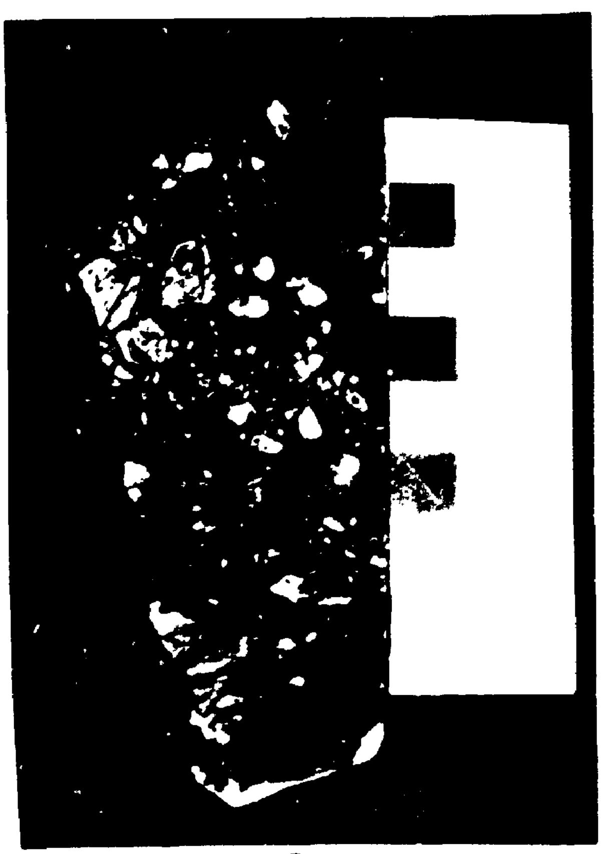
D.) Well foliated quartz sericite - chlorite rock with quartz stringers (white) and chloritic layers (dark).



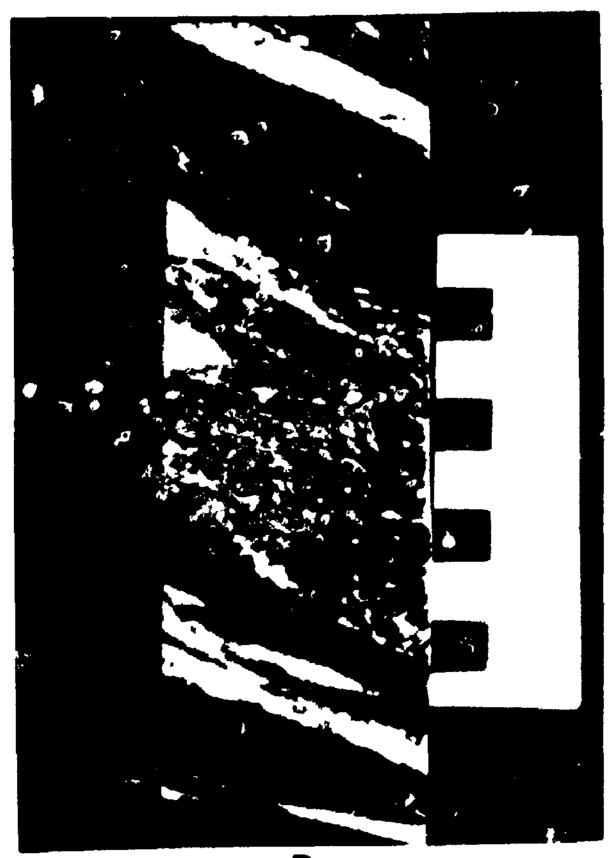
A



B



C



D

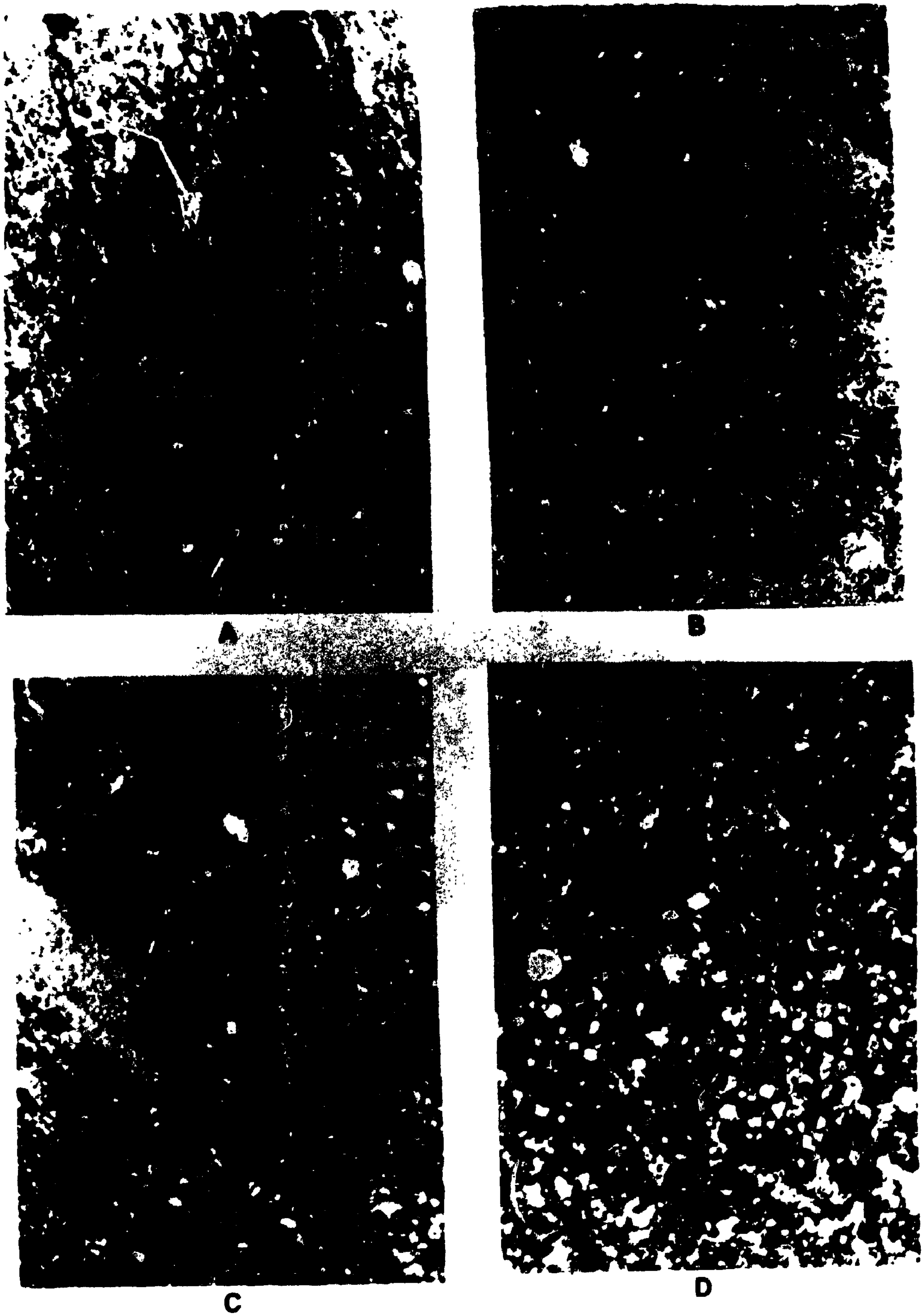
Plate 3-5. Quartz - sericite - chlorite rocks, Ropes deposit. Photomicrographs are 2 mm across short dimension, photographed in cross polarized light.

A.) Well foliated quartz - sericite - chlorite rock with coarse pyrite extended along the foliation.

B.) Quartz - sericite - chlorite rock with light colored sericite rich domains pseudomorphic after feldspar phenocrysts. Black grains are pyrite. Fine grained pyrite is both within relict phenocrysts and also in darker colored matrix; Ropes main ore zone.

C.) Quartz - sericite - chlorite rock with slight alignment of fine grained pyrite along foliation, which trends from upper left to lower right (arrow).

D.) Granoblastic quartz in aphanitic sericite matrix, darkest grains are fine grained pyrite.



A B C D

3

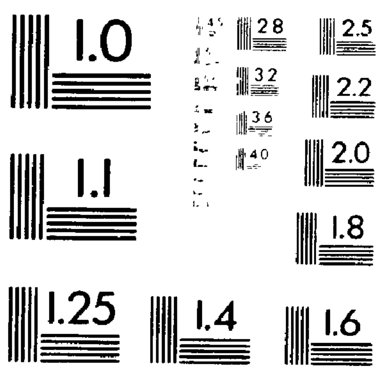


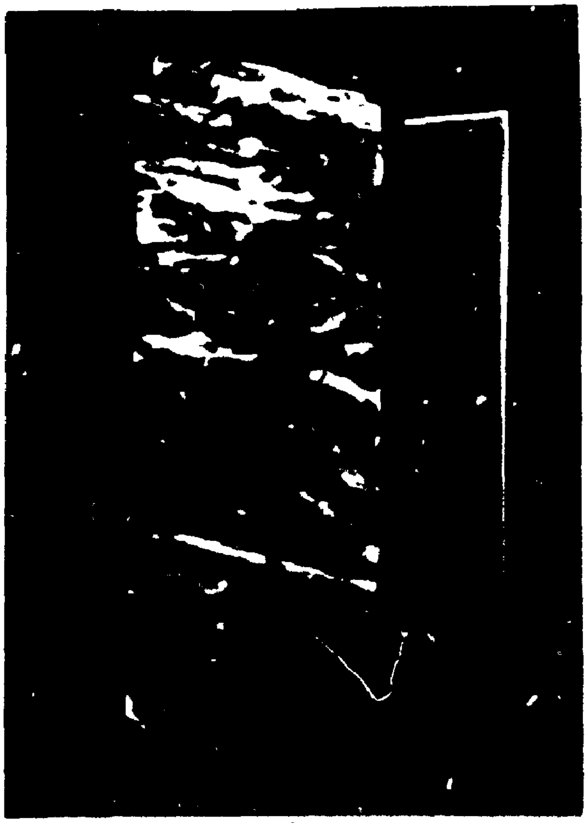
Plate 3-6. Compositionally layered carbonate - quartz - chlorite rocks and carbonate - talc rocks from the Ropes deposit. Scale bars are in cm.

A.) Well foliated carbonate - quartz - chlorite rock with light colored lenses of carbonate, dark chlorite foliations, and fine grained carbonate - quartz layers.

B.) Carbonate - quartz - chlorite rock with coarse grained podiform lenses of white ferroan dolomite.

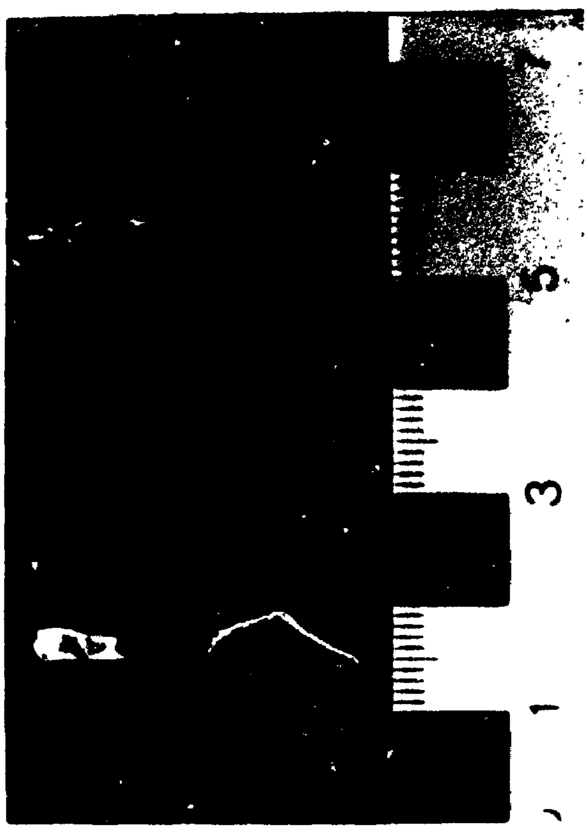
C.) Carbonate - talc rock with sigmoidal S - fabric cut by planar chlorite rich C - fabric.

D.) Irregularly foliated carbonate - talc rock with minor chlorite as discontinuous folia. Small dark grains are magnetite and chromite commonly surrounded by Cr rich chlorite.

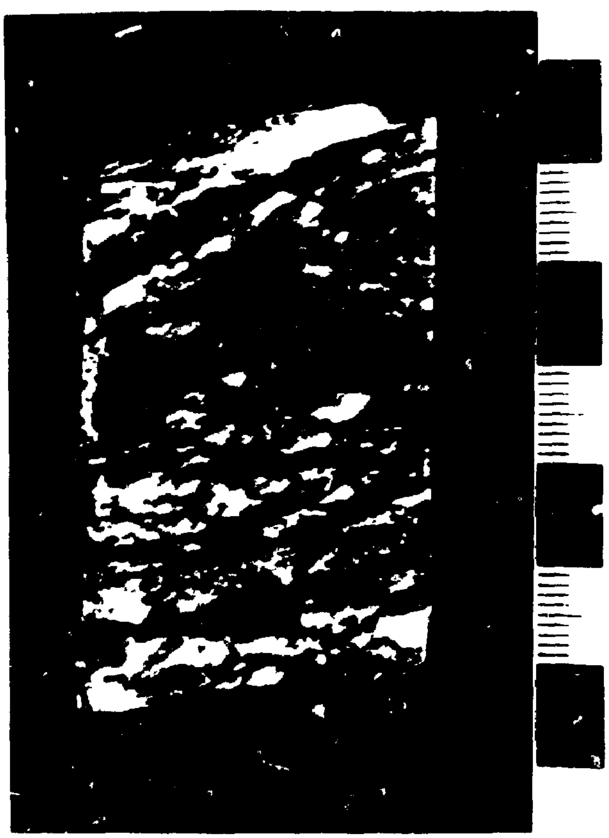


A

B



C



D

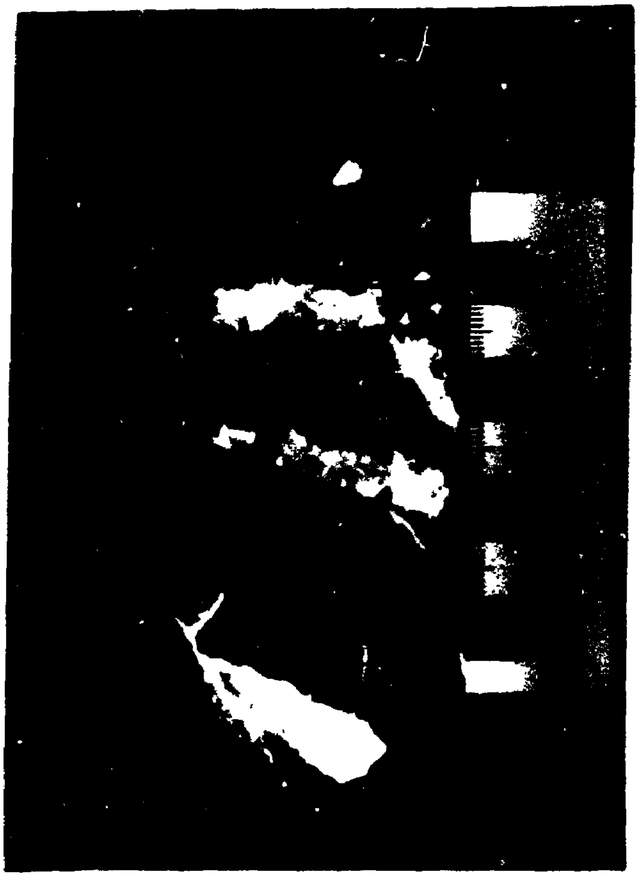
Plate 3-7. Carbonate - quartz - chlorite rocks from Ropes deposit.

A.) Compositional layering defined by carbonate rich white layers and chlorite rich dark layers trends vertically in photograph, cut by late coarse grained white dolomite veins. Scale bar in cm.

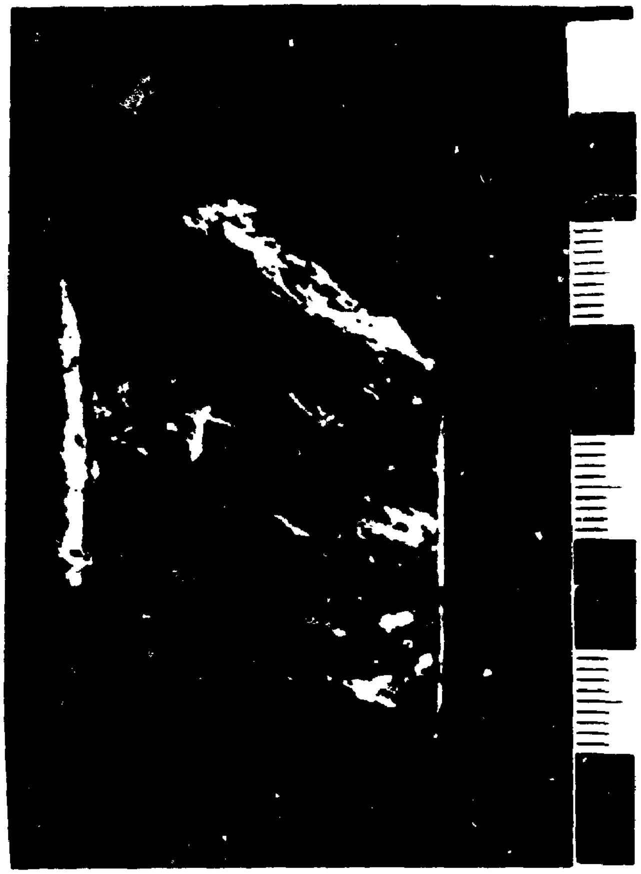
B.) Breccia with fragments of light colored foliated carbonate - quartz - chlorite rock in dark chlorite - pyrite rich matrix. Scale bar in cm.

C.) Cut surface of drill core with centimeter scale compositional layering in carbonate - quartz - chlorite rock, defined by dark chlorite foliations, coarse grained lenses of white ferroan dolomite and fine grained carbonate - quartz layers. Core boxes are 0.6 m in long dimension.

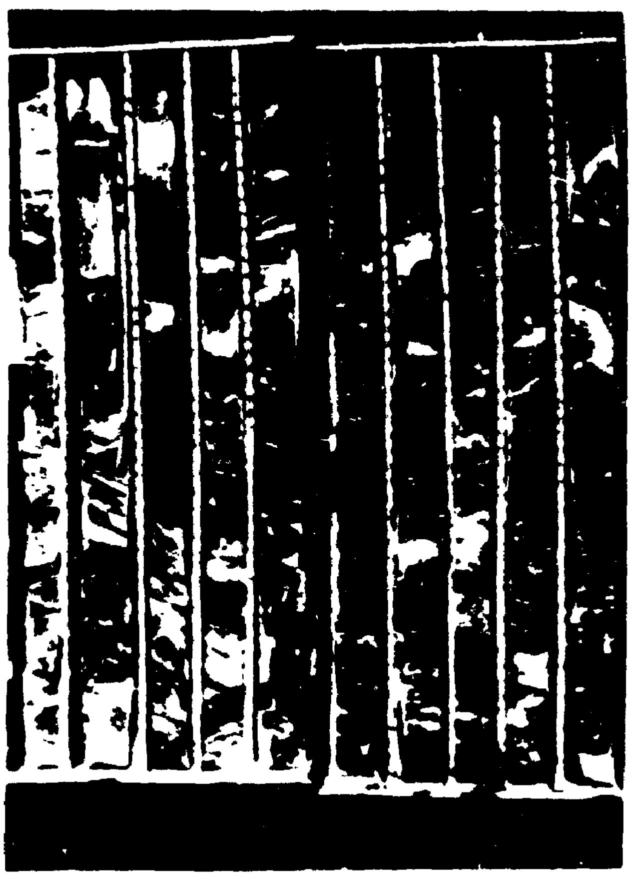
D.) Cut surface of drill core with centimeter scale compositionally layered carbonate - quartz - chlorite rock interlayered with more massive dark colored quartz - sericite - chlorite rock.



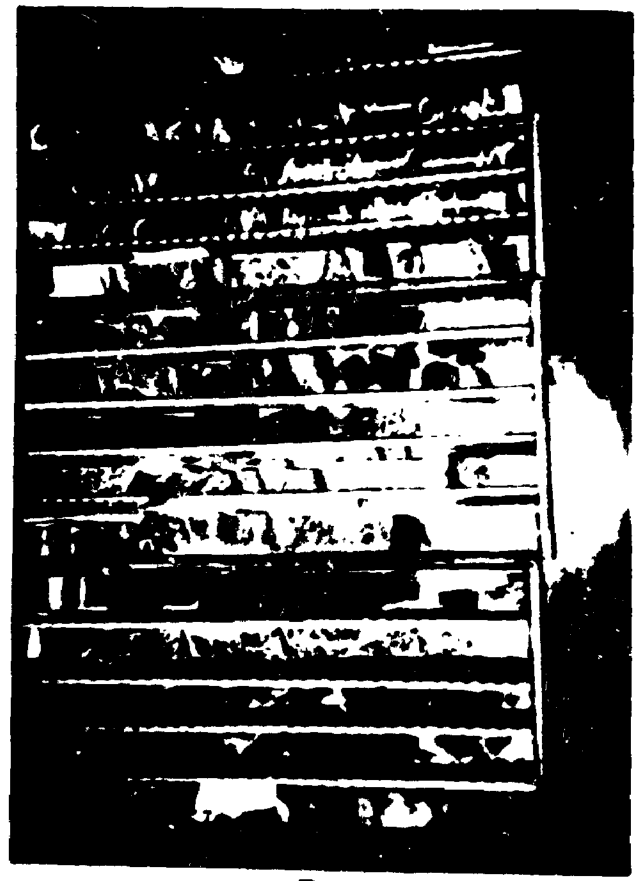
A



B



C



D

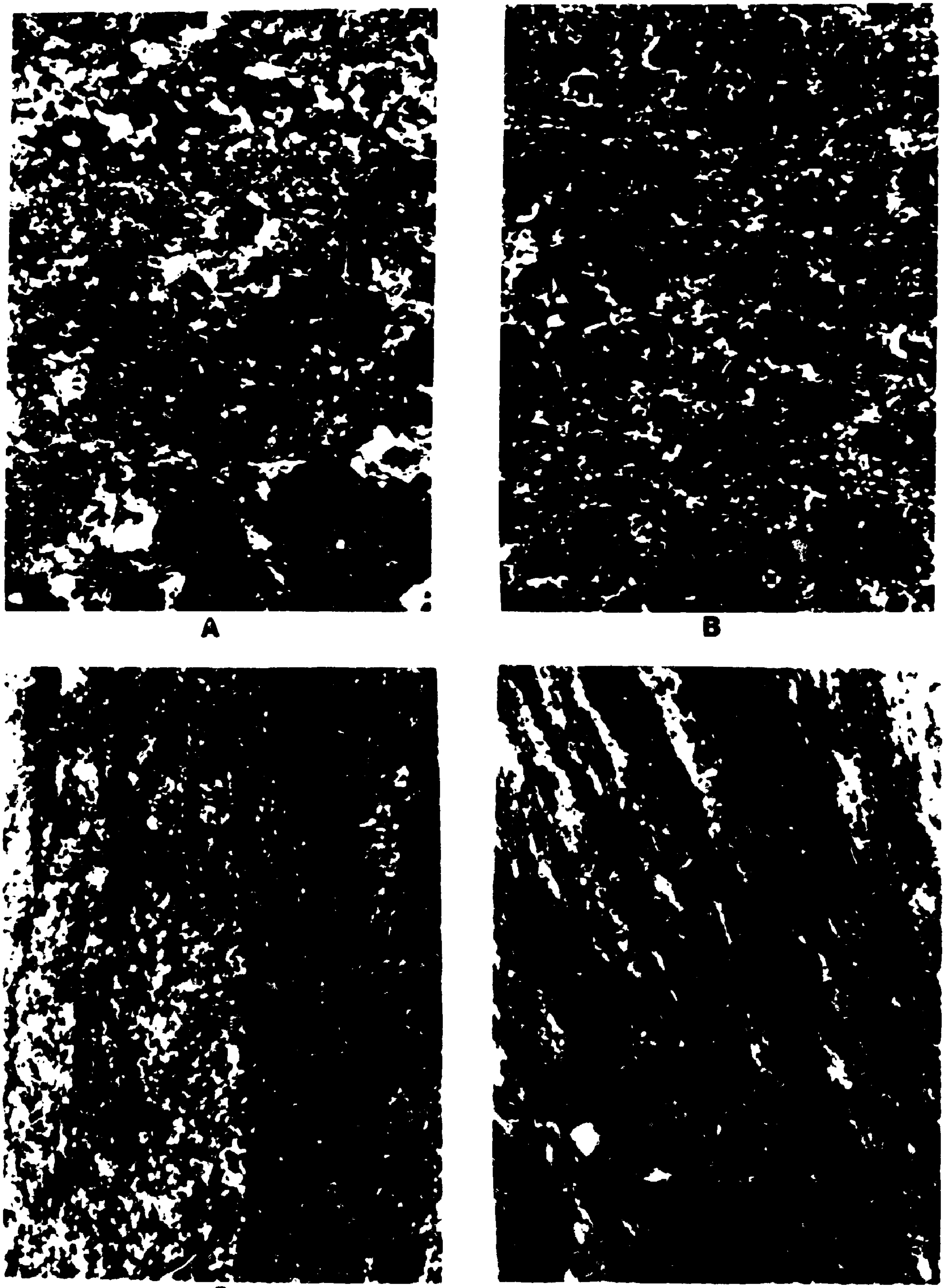
Plate 3-8. Carbonate - quartz - chlorite rocks from the Ropes deposit. Photomicrographs are 2 mm across short dimension, photographed in cross-polarized light.

A.) Crudely compositionally layered carbonate - quartz chlorite rock with coarse grained pyrite as large opaque grains at bottom - center of photogrtaph. Millimeter scale layering is defined by coarser grained carbonate rich laminae and finer grained chlorite - quartz rich laminae.

B.) Millimeter scale compositional layering defined by pyrite rich laminae with coarser grained euhedral pyrite and finer grained carbonate - quartz - chlorite rich laminae.

C.) Millimeter scale compositional banding in carbonate-quartz - chlorite rock defined by alternating chlorite rich and chlorite poor layers.

D.) Well foliated carbonate - quartz - chlorite rock with crenulation defining micro - buckles in the foliation.



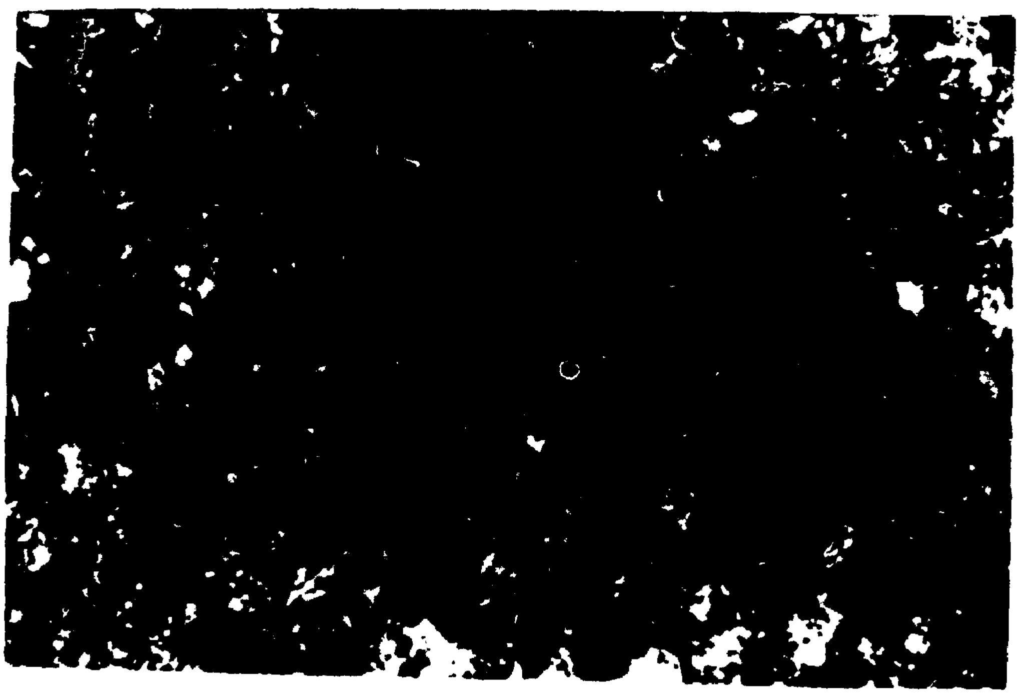
A B C D

Plate 3-9. Microcrystalline carbonate - quartz rock from the Ropes deposit. Photomicrographs are 2 mm across short dimension, photographed in cross polarized light.

A.) Fine grained matrix of ferroan dolomite and quartz with coarser grained patches of dolomite. Opaque grains are pyrite.

B.) Coarser grained white dolomite with subequal matrix of finer grained quartz and ferroan dolomite.

A



B

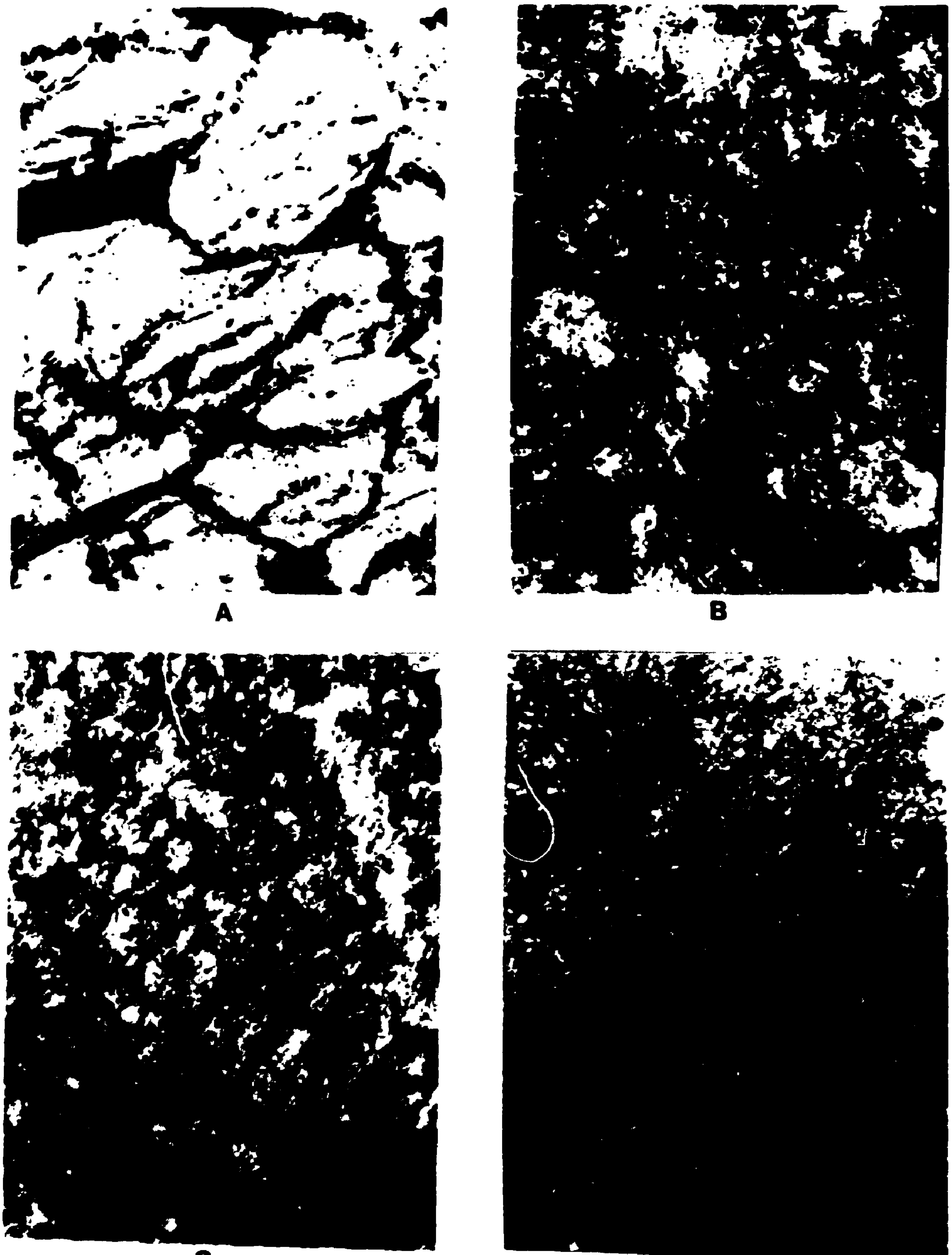
Plate 3-10. Progressive alteration of serpentinitic peridotite from the Ropes deposit.

A.) Serpentinitic peridotite from the Ropes deposit. Blocky white domains are serpentine pseudomorphs after cumulate textured olivine, dark areas are fine grained magnetite rich intercumulus material. Photomicrograph is 2 mm across short dimension, photographed in plane polarized light.

B.) Carbonate rich serpentinitic peridotite. Dolomite, magnesite, and talc with remnant serpentine in centers of domains which are pseudomorphic after original cumulate textured olivine. Dark curvilinear boundaries surrounding the carbonate rich domains are fine grained magnetite rich areas after domains of intercumulus material. Photomicrograph is 2 mm across short dimension, photographed in cross polarized light.

C.) Carbonate - talc rock, with blocky to rounded domains of dolomite, magnesite, and talc after original igneous minerals. Photomicrograph is 5 mm across short dimension, photographed in cross polarized light.

D.) Complete carbonate - talc alteration. Very subtle pseudomorphs after original igneous minerals are visible at top center of photograph as rounded to blocky, light colored carbonate - talc rich domains. Photomicrograph is 5 mm across, photographed in cross polarized light.



A B C D

Flate 3-11. Carbonate - talc rocks and serpentinitic peridotite from the Ropes deposit.

A.) Fine grained matted textured carbonate - talc rock. Photomicrograph is 2 mm across short dimension, photographed in cross polarized light.

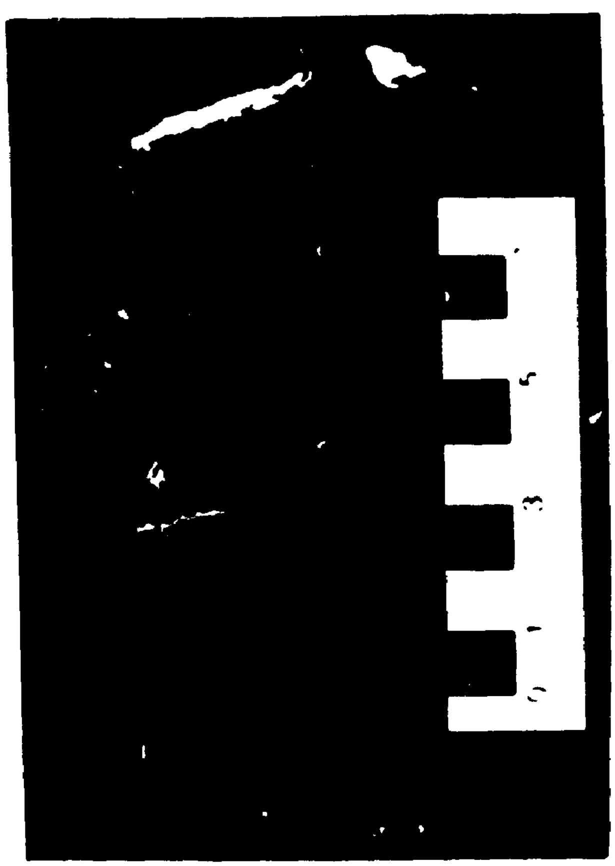
B.) Relatively coarser grained carbonate - talc rock. Opaque minerals are pyrite, magnetite, and minor chromite. Photomicrograph is 2 mm across short dimension, photographed in cross polarized light.

C.) Serpentinitic peridotite from the Ropes deposit, with 2 to 5 mm rounded to blocky serpentine pseudomorphs after original cumulate igneous minerals. Scale bar is in cm.

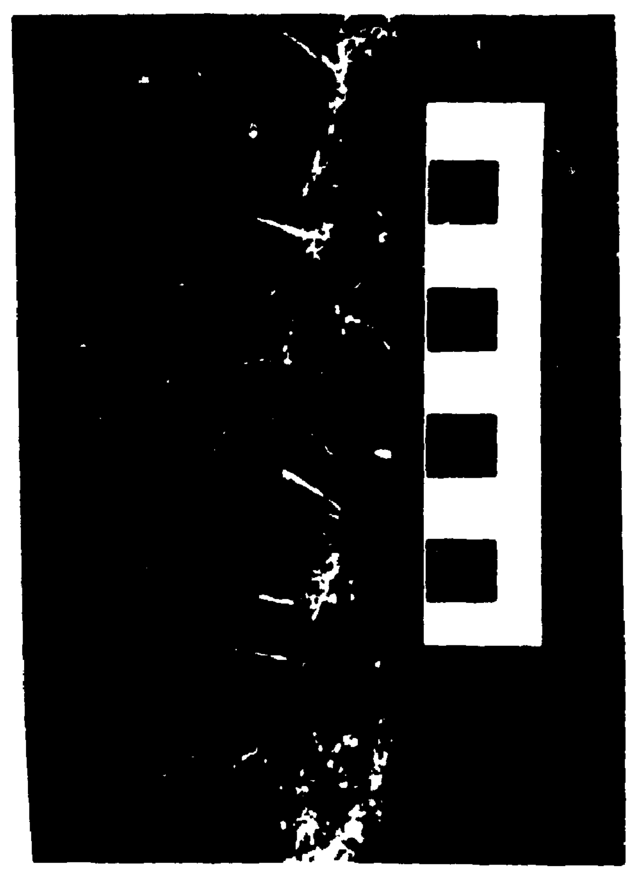
D.) Felted textured serpentinite with chrysotile and carbonate rich zone, cut by white dolomite filled fractures. Scale bar is in cm.

A

B



C



D

3.2 Major Rock Types of the Ropes Gold Deposit

3.2.1 Quartz - Sericite - Chlorite Rock

The main host for gold is light green, massive to slightly foliated, fine grained, quartz - sericite - chlorite rock. This rock is an 080° trending layer up to 40 m thick on the 800 mine level (map plate 4), but narrows toward the surface and toward the east to less than 6 m thick (map plate 3). It is complexly interlayered with carbonate - quartz - chlorite rock, especially west of the Ropes main ore zone (map plate 3) and in the mine (map plate 4). The rock has quartz grains 50 to 100 microns in diameter in a randomly oriented to moderately aligned sub 20 micron quartz and sericite matrix with subordinate chlorite. Randomly oriented to moderately aligned, 1 to 2 mm, angular, rectangular mats of felted sericite up to 2 mm in length, comprised of individual sericite grains less than 10 microns in size and minor quartz, are enveloped in this matrix and have an external habit identical to plagioclase phenocrysts in dacite tuff immediately west of the deposit. This textural change is gradational from a point 200 meters west of the Ropes main ore zone eastward into the Ropes main ore zone and is characterized by increasing sericite in plagioclase phenocrysts and an increase in the abundance of quartz and sericite in the matrix, with a corresponding decrease in feldspar. Therefore, sericite rich mats in the quartz - sericite - chlorite rock of the deposit (plate 3-1c) are interpreted as pseudomorphs after plagioclase phenocrysts (plate 3-1a). These sericite pseudomorphs are up to 20 percent of the rock. Uncommon clasts, 1 to 2 mm in diameter and composed of microcrystalline aggregates of quartz, may represent pseudomorphs of quartz phenocrysts which now have subgrain development (plate 3-2d). Chlorite - quartz fragments, which may be mafic volcanic rock fragments or pseudomorphed mafic mineral phenocrysts, are less common. Chlorite is generally a subordinate component of the rock at less than 10% and occurs both dispersed in the matrix and locally as coarser laths along foliation. Ferroan dolomite is locally a minor component of the matrix. The rock is layered locally with 5 mm thick lenses of sericite rich and alternating more chlorite rich laminae (plate 3-2c).

Gold abundance is generally greatest where very fine to aphanitic pyrite is 5 to 8% of the rock, quartz and sericite are most abundant, and chlorite is least abundant (plate 3-4 a,b). However, this generality does not apply to the chloritic, pyritic, easternmost rim of the Ropes main ore zone. Rock with greatest gold abundance contains only trace amounts of carbonate minerals, compared with greater but still minor concentrations of carbonate minerals in less auriferous parts of the quartz - sericite - chlorite rock. Fine pyrite, 50 to 100 microns in diameter, is dispersed in the rock matrix and less commonly within sericite pseudomorphs after plagioclase (plate 3-5b, c) and is not confined only to quartz veinlets or to foliation planes. It locally has pressure shadows or pressure fringes but is rarely broken. Coarser porphyroblastic pyrite, 0.5 to 1 mm in diameter, is near quartz veinlets and also along chlorite foliations. It is enclosed locally by quartz overgrowths and is fractured and separated in the direction of the foliation (plate 3-5a). Rock with only coarser pyrite is not ore. Where both types of pyrite occur together, the fine pyrite is less or unaccompanied by strain indicators. Anastomosing quartz veinlets less than 1 mm thick make up several percent of the rock (plate 3-2c). Quartz in the veinlets commonly has undulatory extinction and local mortar texture. Rock outside of the ore zones contains less than 2% very fine pyrite.

There are several minor rock types within the Ropes deposit. Dark green phyllitic fine grained chlorite - quartz rock is a discontinuous layer up to several meters thick along the south contact of the quartz - sericite - chlorite rock with the carbonate - quartz - chlorite rock. It has rare angular fragments of quartz - sericite rock, up to several centimeters in diameter. A layer of white microcrystalline, ferroan dolomite - quartz rock (plate 3-9) up to 2 m thick strikes 080° along with a thin layer of carbonate - quartz - chlorite rock through the center of the trend of the quartz - sericite - chlorite rock (map plates 4, 5). This ferroan dolomite - quartz rock separates the trend of quartz - sericite - chlorite rock into a south and a north half within part of the deposit. It contains up to 80 ppb Au and minor pyrite. Although the microcrystalline ferroan dolomite - quartz rock does not contain ore grade gold concentrations, it has a consistent position along the north side of the Ropes main ore zone, particularly for the central and east parts of the main ore zone (map plate 4). A fine grained, felt textured basalt dike trends approximately north across the layered rock sequence at the west end of the Ropes deposit (map plate 5). It cuts ore locally but is barren, and therefore is considered post ore.

A rock sample suspected to be a lamprophyre was collected from the Ropes deposit. Its anomalous chemistry and petrography were not recognized until after its location in the mine became inaccessible, hence the extent and contact relations of this rock type are not known. Sample RISO-16 from the west end of the 420 level is 10% 0.5 to 2 mm tabular to hexagonal domains comprised of aphanitic dark chlorite in an aphanitic sub 20 micron matrix of major felted sericite and minor quartz. The chlorite domains are possibly pseudomorphic after biotite. The assayed Au concentration is 61.9 g/tonne. The rock has SiO_2, total alkalis, Zr, Rb, P, V, Ni, and Ce abundances comparable to an ultramafic lamprophyre dike at the Con mine in Yellowknife, NWT (D. Webb, 1987, University of Western Ontario, personal communication) (table 3-1). The probable presence of biotite phenocrysts further indicate that the sample could be a lamprophyre.

The overall 070° striking trend of quartz - sericite - chlorite rock which hosts the Ropes main and northwest ore zones interfingers with carbonate - quartz - chlorite rock west of the deposit, and does not continue west of the northwest ore zone (map plate 3). East of the deposit, the trend of quartz - sericite - chlorite

Table 3-1. Comparison of possible lamprophyre from the Ropes deposit with ultramafic lamprophyre from the Con mine, Yellowknife, NWT.

		Sample RISO-16 (Ropes mine)	Ultramafic Lamprophyre (Con mine)
(wt.%)	SiO_2	38.0	41.7 +/- 1.8
"	Na_2O+K_2O	5.27	4.7 +/- 2.1
"	P	1.58	1.29 +/- 0.21
(ppm)	Zr	410	330
"	Rb	170	270
"	Cr	140	360
"	V	200	220
"	Ni	150	190
	Ce_{cn}	462	850

rock does not continue at surface beyond 300 m east of the main ore zone (map plate 3). The east northeast projection of the trend is instead marked by a zone of carbonate - talc rock within the serpentinitic peridotite. Phelps - Dodge drill hole DLP - I (map plate 2) intersected four zones of dark green to black, very fine grained, massive, granular textured quartz - feldspar - chlorite - biotite - sericite rock ranging from 0.5 to 4 m thick within carbonate - talc rock within serpentinitic peridotite 800 m east northeast of the Ropes main ore zone. This quartz - feldspar - chlorite - biotite - sericite rock lacks a foliation, unlike the foliated quartz - sericite - chlorite rock which hosts the Ropes deposit, indicating that it may be late dikes intruded into carbonate - talc rich zones. A well defined magnetic low with negative relief of up to 3000 gammas follows the trend of quartz - sericite - chlorite rock through the Ropes deposit, continues east northeast, and passes immediately north of the ground penetrated by drill hole DLP-I (map plate 6). Drill hole DLP-1 probably penetrated a separate narrow, east northeast trending magnetic low that lies south of the main magnetic low.

A separate trend of quartz - sericite - chlorite rock, the Middle trend, is north of the Ropes deposit and is separated from it by a zone of carbonate - quartz - chlorite rock and carbonate - talc rock (map plate 3). The strike of the Middle trend changes from 070° north of the deposit to 045° west and southwest of the deposit, where it trends along the northwest contact of the serpentinitic peridotite. The Middle trend has similar composition, textures, and minerals compared to the quartz - sericite - chlorite rock which hosts the Ropes deposit, and is likewise interpreted as having a dacite tuff protolith. It does not host any major Au concentrations in its explored parts with only isolated 0.5 to 1.5 m drill core intervals of 3.4 to 8.5 g/tonne Au west of the deposit.

A 30 m thick northwest trending zone of serpentinitic peridotite, carbonate - talc rock, and carbonate - quartz - chlorite rock separates the Middle trend from the major area of dacite tuff west of the deposit (map plate 3). A 15 to 30 meter thick zone of quartz - sericite - chlorite rock is directly west of this northwest trending zone of serpentinitic peridotite and associated rocks. The quartz - sericite - chlorite rock here is similar to the rock which hosts the Ropes deposit, and is likewise interpreted as having a dacite tuff protolith. It grades northwest across strike into dacite tuff, lapilli tuff, and tuff breccia (map plate 3; plate 2-3d) which retain clear primary textures such as 1 to 2 mm feldspar phenocrysts (plate 3-3c), quartz phenocrysts and dacite fragments. These latter rocks contain veinlets of quartz, pink to brick red potassium feldspar, calcite, and pyrite which have sharp contacts with the host rocks, with little or no alteration extending into the host rock surrounding the veins, in marked contrast to rocks rich in secondary quartz, sericite, and chlorite within the Ropes deposit. Feldspar porphyritic hypabyssal dacite sills intrude the dacite tuff 50 m west of the northwest trending zone of serpentinitic peridotite and associated rocks (map plate 3). The contact between the quartz - sericite - chlorite rock near the Ropes deposit and the more pristine dacite tuff to the west is coincident with a lineament on aerial photographs named the I-18 structure (Lehnertz, 1987).

Lenses of banded quartz - magnetite iron formation within dacite tuff west of the Ropes deposit are up to 100 m long and have dip extents of up to 200 m (map plate 3). The iron formation is alternating cm thick laminae of microcrystalline quartz and magnetite (plate 3-3d). There is pyrite both as conformable layers and as discordant pyrite veinlets, but even where pyritic, it is not auriferous. Most of the iron formations are stratigraphically underlain by fine grained graywacke (plate 2-3c) and siltstone which are confined to the same areal extent as the iron formations, hence the iron formations are localized as caps in the top parts of channels within the volcanic sequence, which are filled with clastic sedimentary rocks. The graywacke has sand to silt sized quartz, feldspar, and lithic fragments of fine grained andesite and dacite in an aphanitic matrix, with bedding defined by mm to cm scale parallel sided laminations alternately rich and poor in the sand sized particles (plate 3-3b). Based on limited drilling of the downplunge extent of the northernmost known lense, the iron formation has a greater extent downplunge to the east than it does along strike. The strike of the iron formations, graywackes, and dacite tuffs northwest of the Ropes deposit is 040°, with 70° to 80° southeast dips (map plate 3).

Hypabyssal diabase has uniform medium grained blocky plagioclase crystals pseudomorphed by sericite, and former mafic mineral domains, probably pyroxene, pseudomorphed by dolomite and chlorite. The mineral domains are in crude planar alignment. Basalt has former pyroxene domains pseudomorphed by dolomite and chlorite, in an aphanitic matrix of granular dolomite and chlorite with minor leucoxene. The matrix has faint flow structures around the former phenocrysts. These mafic rocks are more common within the deep west part of the Ropes deposit and west of the deposit, where they make up approximately 5% of the volcanic rocks.

Andesite is 2 to 3 mm plagioclase phenocrysts with sericite and mafic domains of clinozoisite and chlorite, possibly after pyroxene, in a matrix of very fine grained plagioclase with sericite, quartz, and chlorite. It is most common northwest and west of the deposit where it is approximately 10% of the volcanic rocks.

3.2.2 Carbonate - Quartz - Chlorite Rock

Carbonate - quartz - chlorite rock envelopes the quartz - sericite - chlorite rock and is complexly interlayered with it, particularly toward the west end of the Ropes deposit (map plates 4, 5; plate 3-7d). It is abundant ferroan dolomite, and lesser quartz and chlorite. There is minor sericite in some parts and variable amounts of talc occurs in others, but these two minerals are generally mutually exclusive. Contacts with the quartz - sericite - chlorite rock are sharp in a direction across the strike of the rock type, but are locally gradational along strike. Barren milky quartz veins up to 10 cm thick occur locally and are conformable to the contact. Minor carbonate minerals are present in the quartz - sericite - chlorite rock near its contacts with the carbonate - quartz - chlorite rock, and minor sericite is present in the carbonate - quartz - chlorite rock near its contacts with quartz - sericite - chlorite rock. Carbonate - quartz - chlorite rock has up to 150 ppb Au, and quartz - rich parts of the carbonate - quartz - chlorite rock only very locally contain several percent pyrite and up to 1 ppm Au. Locally the carbonate -quartz - chlorite rock is brecciated along the south side of the Ropes deposit, with angular fragments of carbonate veined, carbonate - quartz - chlorite rock in a chlorite - rich matrix (plate 3-7b).

Carbonate - quartz - chlorite rock is generally compositionally layered on a scale of several millimeters, but locally is massive. Layering is defined by lense - like fine to medium grained white carbonate laminae, chlorite foliation, and quartz - chlorite - rich laminae (plate 3-6a, b). The rock is increasingly talcose toward the contact with carbonate - talc rock. Coarse grained, barren, white dolomite veins up to 5 cm thick cut across all other features and are several percent of the rock (plate 3-7a). Carbonate - quartz - chlorite rock is not only within the deposit but also in a zone up to 60 m thick on its north side (map plate 3) where it contains thin layers of the other three main rock types. Carbonate - quartz - chlorite rock is in local lenses along the northeast striking contact of the Deer Lake Peridotite southwest and northwest of the Ropes deposit.

The carbonate - quartz - chlorite rock is interpreted as an alteration product of a serpentinitic peridotite protolith. This interpretation is based on the following observations: 1.) The carbonate - quartz - chlorite rock has sharp contacts with the quartz - sericite - chlorite rock, but gradational contacts over one to several meters with the carbonate - talc rock and serpentinitic peridotite, suggesting a genetic association with the serpentinitic peridotite and carbonate - talc rocks. 2.) Features interpreted as S - C tectonic fabric (Lister and Snokes, 1984) are common in the carbonate - quartz - chlorite rock, (plate 3-6c) and furthermore the carbonate - quartz - chlorite rock has lense - like layers (plate 3-

6c, d) rather than regular, sheetlike layers that might be characteristic of finely banded chemical sediments such as occur in some carbonate rich cherts or banded quartz - magnetite iron formation, hence an origin for the layering as lithons by shearing of an ultramafic protolith is considered more likely than an origin as primary layers in a chemical sediment. 3.) Volumetrically, the vast majority of the carbonate quartz - chlorite rock is between the more SiO_2 rich quartz - sericite - chlorite rock, and the serpentinitic peridotite and carbonate - talc rocks. Serpentinization of the peridotite preserved igneous textures, and was therefore most likely a volume for volume replacement (Thayer, 1966). Constant volume serpentinization would have released large amounts of MgO and SiO_2 to the surrounding rocks (Best, 1987), forming the voluminous carbonate - quartz - chlorite rocks which bound and are interlayered with the quartz - sericite - chlorite rocks, and which are mostly ferroan dolomite with lesser quartz. A possible reaction is: 5 Mg_2SiO_4 (219 cm^3) + 4 H_2O = 2 $Mg_3Si_2O_5(OH)_4$ (215 cm^3) + 4 MgO + SiO_2 (removed in solution) (Best, 1987, p. 398-399). Large amounts of Ca can also be lost from ultramafic rocks and added to the country rocks during serpentinization (Page, 1967 a, b; Coleman, 1971; Coleman and Keith, 1971; Arndt and others, 1977). 4.) Abundances of less mobile trace elements (figures 3-6, 3-7, 3-8), principal components factor analysis of abundances of major and trace elements in whole rock (figure 3-9; appendix C-3), and abundances of chondrite - normalized rare earth elements (figure 3-10) all indicate that the carbonate - quartz - chlorite rock is compositionally identical or similar to the serpentinitic peridotite and carbonate - talc rock.

Therefore, it is suggested here that the carbonate - quartz - chlorite rock is an alteration product of a peridotite protolith, in which less mobile element and rare earth element abundances are nearly unchanged from those of the protolith. An interpretation of the carbonate - quartz - chlorite rock as a mixture, either by surficial depositional processes or by shearing of dacite and peridotite end members is not indicated, because there is no third group of rocks representing a mix of the two end members. Furthermore, the interpretation that the carbonate - quartz chlorite rock is a chemical sediment derived largely from leaching of a peridotite source is considered very unlikely because, in the case of the carbonate - quartz - chlorite rock, it would require that the less mobile elements and rare earth elements were leached, carried in solution, and deposited in the same abundances as they existed in the peridotite source. That these elements would be dissolved in the exact proportions in which they occur in the source rock is unlikely.

3.2.3 Serpentinitic Peridotite and Carbonate - Talc Rock

The interlayered quartz - sericite - chlorite rock and carbonate - quartz - chlorite rock are bound on north and south by elongate masses of serpentinitic peridotite. There are also several smaller serpentinitic peridotite bodies enclosed within the carbonate - quartz - chlorite rock on the north side of the Ropes deposit. The largest of these bodies is the north wall of the Ropes deposit (figure 3-1; map plate 3). The rock is dark gray to green, mostly fine grained, with major serpentine, subordinate talc and carbonate, minor chlorite, and accessory chromite and magnetite. The serpentine is a mixture of felted chrysotile and oriented plates of antigorite. Commonly it has a relict cumulate texture (plate 3-10a, 3-11c) of 1 to 3 mm serpentine pseudomorphs after major olivine and subordinate pyroxene. The pseudomorphs are surrounded by rims of talc, carbonate minerals, and accessory fine grained magnetite and chromite, Locally the rock is dark green, felted textured serpentine which lacks a pseudomorphic texture. The serpentinitic peridotite is increasingly carbonate rich toward its borders, although the relict texture is commonly continuously preserved (plate 3-10b to d). Fibrous chrysotile veinlets in the serpentinitic peridotite are locally pseudomorphed by carbonate. Au abundance is typically less than 30 ppb even in close proximity to the deposit.

Massive to well foliated, gray to dark green, very fine grained carbonate - talc rock occurs around the margins of serpentinitic peridotite (map plate 3; plate 3-11a, b). Chlorite, serpentine, magnetite, chromite and pyrite are minor phases. The carbonate - talc rock has gradational contacts over one to several meters with serpentinitic peridotite and with talc - rich parts of the carbonate - quartz - chlorite rock. Talc and carbonate contents are generally subequal. There are minor zones of dominantly talc up to several feet thick. The carbonate mineral in the carbonate - talc rock is dominantly ferroan dolomite with minor magnesite. Au abundance is from less than 30 ppb to approximately 100 ppb in the carbonate - talc rock. The spatial association of carbonate - talc rock with the margins of serpentinitic peridotite, the gradational contacts with serpentinitic peridotite, and similar abundances of Cr and less mobile trace elements in the carbonate - talc rock and serpentinitic peridotite (appendix C-1) indicate that the carbonate-talc rock is the altered margins of serpentinitic peridotite.

3.3 Chemical Composition of Rocks in the Ropes Deposit

3.3.1 Distribution of Major Oxides and Trace Elements

Abundance of major oxide and trace elements for 36 rock samples from the Ropes deposit (appendix C-1) define two major groups of rocks (table 3-2): quartz - sericite - chlorite rocks (group 1); and, carbonate - quartz - chlorite rocks, carbonate - talc rocks, and serpentinitic peridotite (group 2).

The rock sequence of the Ropes deposit has symmetrical element zonation patterns centered about the quartz - sericite - chlorite rock with respect to many major and trace constituents (figures 3-4, 3-5). SiO_2, Al_2O_3, K_2O, TiO_2, P_2O_5, Rb and Zr decrease, and MgO and Cr increase, outward from the center of the quartz - sericite - chlorite rock. CaO, Sr, Y, and CO_2 have maxima

Table 3-2: Comparison of two groups of rocks from the Ropes deposit

	Group 1 (quartz - sericite - chlorite rock)	**Group 2 (carbonate - quartz - chlorite rock; carbonate - talc rock; serpentinitic peridotite**
wt.% SiO_2	>50	<38
wt.% Al_2O_3	>12	< 4
wt.% Fe_2O_3	slightly≤Mg0	0.16 to 0.3 times MgO
wt.% MgO	<14	>20
wt.% Na_2O	> 0.1	< 0.1
wt.% K_2O	> 2	≤ .02
wt.% TiO_2	> 0 .5	<.15
wt.% P_2O5	> .04	≤ .02
wt.% LOI	<8	>11
wt.% CO_2	<4	>12
ppm Cr	<200	>600
ppm Rb	>50	≤20
ppm Zr	>80	<10
ppm Ga	>11	< 5
ppm Ni	<200	>1000
ppm V	>70 (mostly >100)	<70
ppm Ce	>30	<7
ppm La	>20	<2.5
ppm Nd	≥16	3
ppm Sm	≥2.68	<.55
ppm Eu	≥0.72	< .29
ppm Tb	≥.3	0.1
ppm Yb	≤.28	≥1.02
ppm Lu	≥.15	≤.04

Figure 3-4. Chemical variation diagram through the Ropes deposit. Traverse is on 530 level at 450 East. Contacts between rock types are at top of diagram and location of ore zones along traverse are at bottom of diagram.

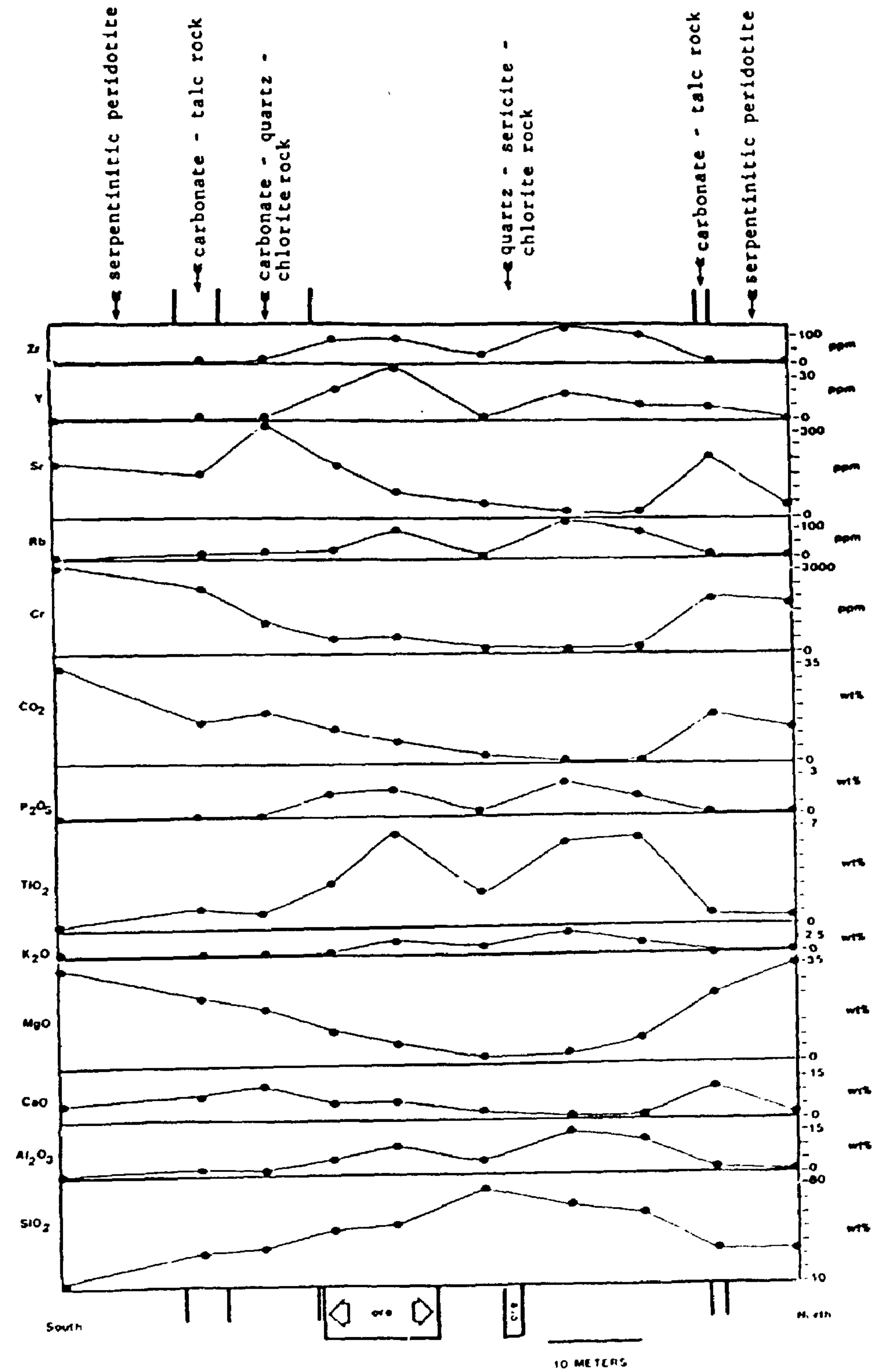
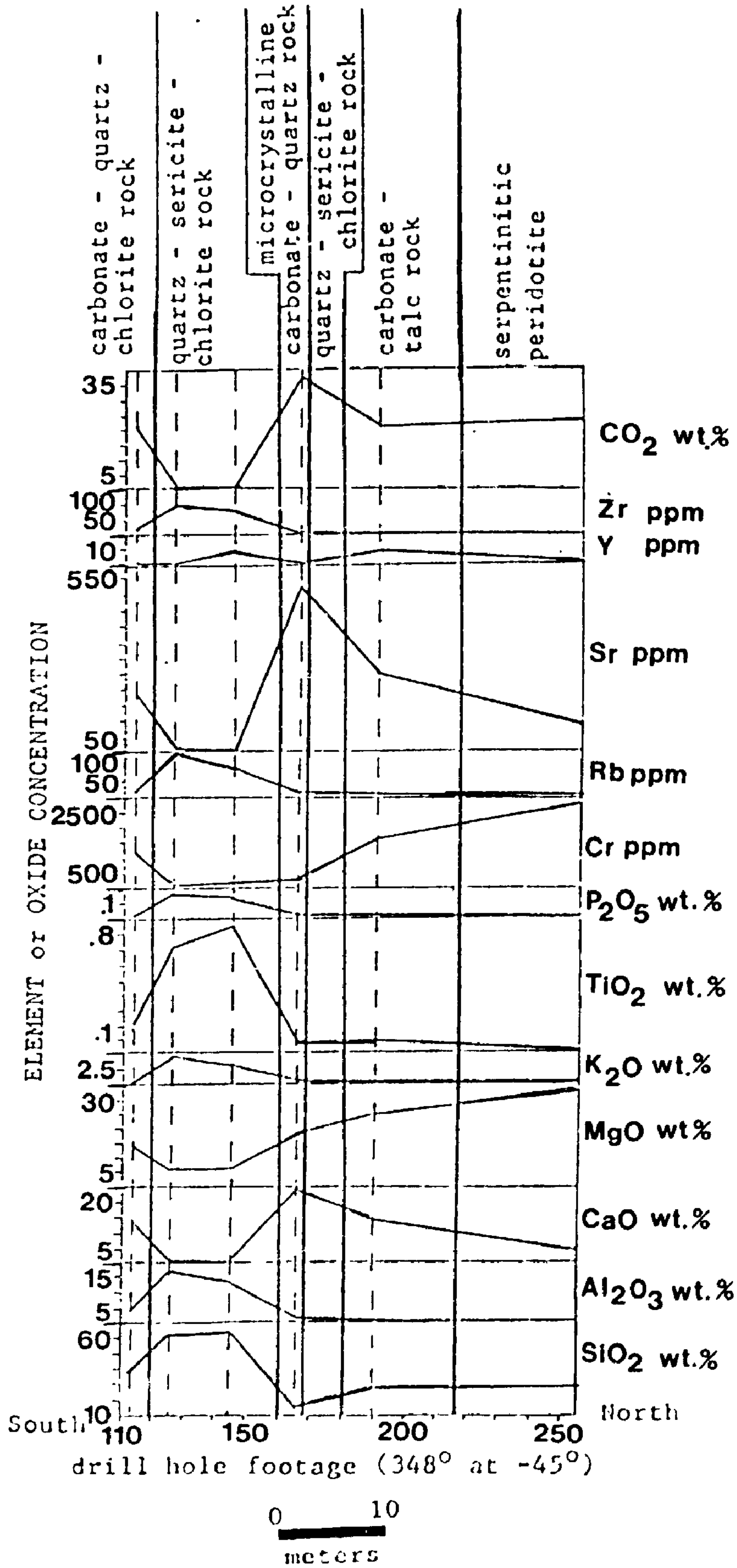

serpentinitic peridotite
carbonate - talc rock
carbonate - quartz - chlorite rock
quartz - sericite - chlorite rock
carbonate - talc rock
serpentinitic peridotite
Zr
Y
Sr
Rb
Cr
CO_2
P_2O_5
TiO_2
K_2O
MgO
CaO
Al_2O_3
SiO_2
ppm
wt%
ore
South
North
10 METERS

Figure 3-5. Chemical variation diagram across the trend of quartz - sericite - chlorite rock 250 m east of the Ropes main ore zone.


carbonate - quartz - chlorite rock
quartz - sericite - chlorite rock
microcrystalline carbonate - quartz rock
quartz - sericite - chlorite rock
carbonate - talc rock
serpentinitic peridotite
ELEMENT or OXIDE CONCENTRATION
CO_2 wt.%
Zr ppm
Y ppm
Sr ppm
Rb ppm
Cr ppm
P_2O_5 wt.%
TiO_2 wt.%
K_2O wt.%
MgO wt%
CaO wt.%
Al_2O_3 wt.%
SiO_2 wt.%
South
North
110
150
200
250
drill hole footage (348° at -45°)
0
10
meters

displaced to both sides of the center (figures 3-4, 3-5). Within quartz - sericite - chlorite rock, none of the major oxides or selected trace elements (appendix C-1) have a unique correlation with Au abundance based on correlation coefficients (appendix C-2).

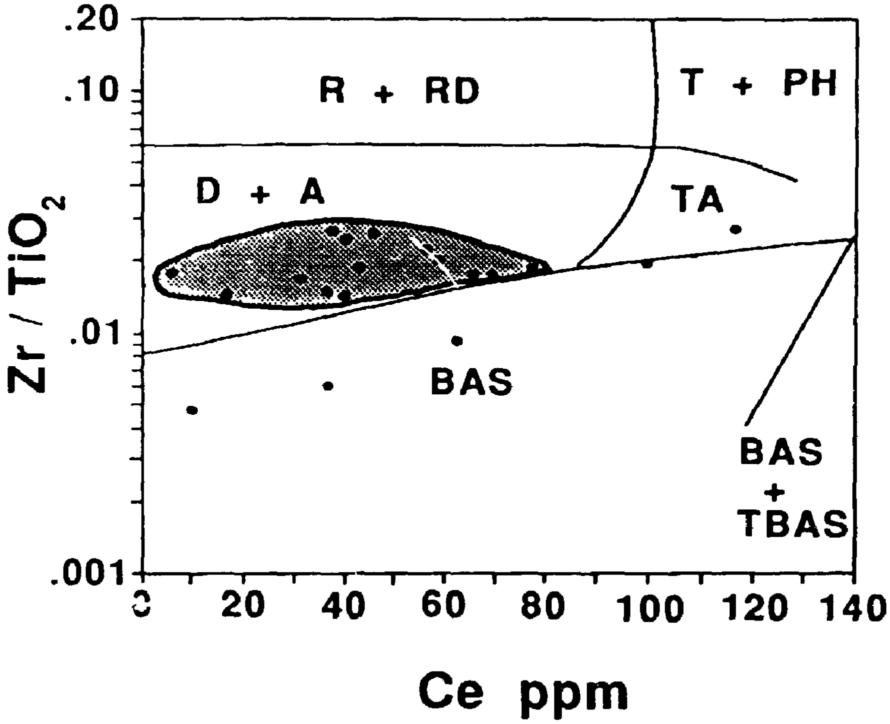
3.3.2 Distribution of Less Mobile Trace Elements

Quartz - sericite - chlorite rocks plot in the dacite to andesite fields, with minor basalt, on less mobile trace element plots (figures 3-6, 3-7, 3-8; appendix A). Serpentinitic peridotite, carbonate - talc rocks, and carbonate - quartz - chlorite rocks have less mobile trace element contents which indicate that they have a peridotite protolith (figures 3-7, 3-8).

3.3.3 Principal Components Factor Analysis

Factor analysis of principal components define groups of elements which vary together and which therefore might be related to the same process (appendix A). Factor 1 accounts for 54% of the total variability (appendix C-3). This factor may be a differentiation index separating group 2 rocks, which have a greater

Figure 3-6. Zr/Ti versus Ce classification of quartz - sericite - chlorite rocks from the Ropes deposit. Method after Floyd and Winchester (1978). Shaded field encloses 14 samples; 5 samples outside this field are plotted as dots. Indicated fields are: R + RD = rhyolite + rhyodacite; T+Ph = trachyte + phonolite; D + A = dacite + andesite; TA = trachyandesite; BAS = basalt; BAS + TBAS = basalt + trachybasalt.



Quartz - sericite - chlorite rocks

Figure 3-7. V versus Ni plot of rocks from the Ropes deposit, indicating two main groups of rocks: 1) Q = quartz - sericite - chlorite rocks (after dacite); 2.) C = carbonate - quartz - chlorite rock; T = carbonate - talc rock; and S = serpentinitic peridotite (after peridotite).

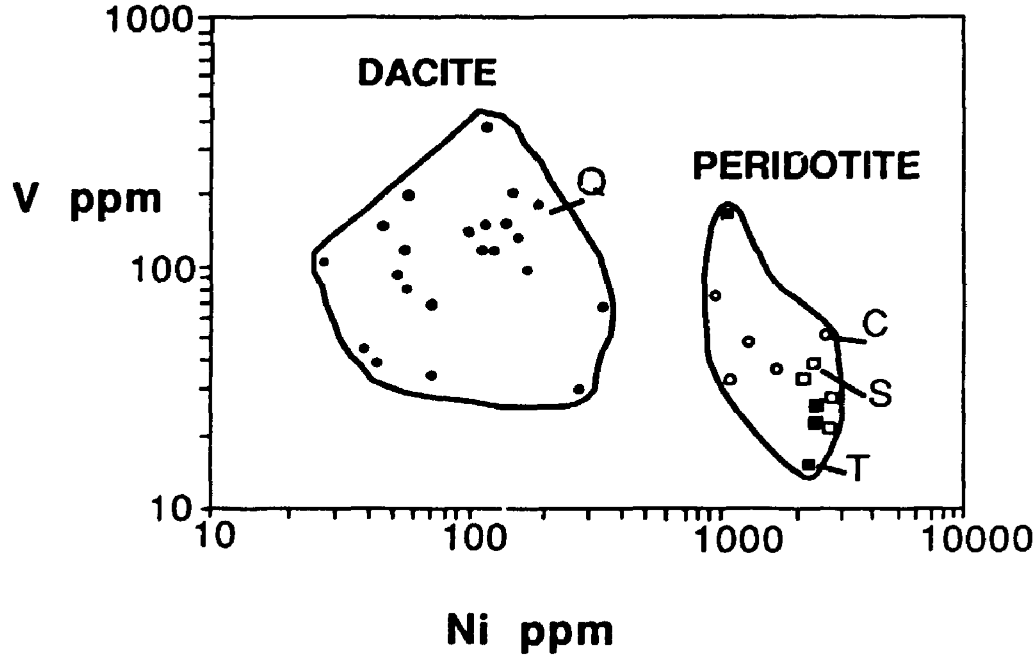
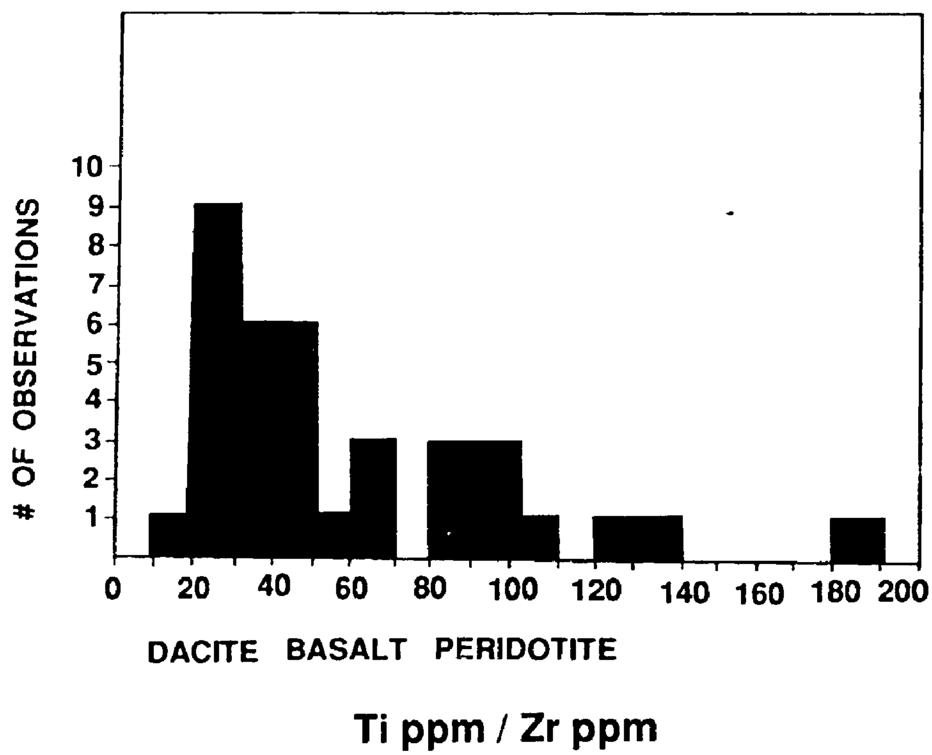

DACITE
PERIDOTITE
Q
C
S
T
V ppm
Ni ppm
1000
100
10
10
100
1000
10000

Figure 3-8. Ti/Zr classification of rocks from the Ropes deposit.



OF OBSERVATIONS
10
9
8
7
6
5
4
3
2
1
0
20
40
60
80
100
120
140
160
180
200
DACITE BASALT PERIDOTITE
Ti ppm / Zr ppm

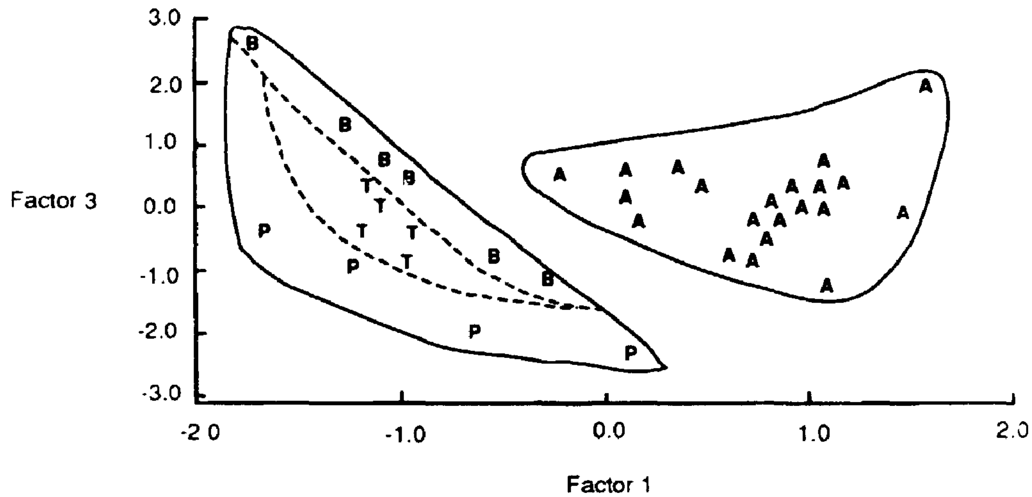
concentration of MgO, from group 1 rocks which have greater concentrations of SiO_2, Al_2O_3, K_2O and TiO_2. In addition, it reflects the effects of increased carbonate in group 2 rocks. Factor 2, which is positively affected by total Fe and H_2O+, and negatively affected by SiO_2, may indicate the abundance of chlorite, which is rich in Fe and H_2O and low in SiO_2. Factor 3 may indicate CaO and Sr in carbonate minerals which influences the factor in the positive direction. The negative influence of H_2O+ may represent the lower abundance of water bearing phyllosilicates in group 2 rocks with high carbonate. Factor 5 is negatively influenced by Na_2O, and may indicate alteration of originally present feldspar to sericite and consequent mobilization of its Na_2O component.

Factor plots indicate a separation of group 1 rocks from group 2 rocks, especially relative to the Factor 1 axis (appendix C-3). This difference probably indicates original difference in protolith between the quartz - sericite - chlorite rocks and the serpentinitic peridotite. Factor plots using factors 2, 4 and 5 do not separate the carbonate - quartz - chlorite rock, carbonate - talc rock, and serpentinitic peridotite from each other, which suggests that little of the internal variability among these rock types is explained by the variables comprising these factors. Factor 1 versus factor 3 has zoning of carbonate - quartz - chlorite rocks, talc - carbonate rocks, and serpentinitic peridotite (figure 3-9 and appendix C-3). Serpentinitic peridotite is characterized by minor influence of factor 3 and minor influence of factor 1, with increased influence of factor 3 and factor 1 in the carbonate - quartz - chlorite rocks. A large increase in the influence of factor 1 accompanies the quartz - sericite - chlorite rocks. Factor 1 versus factor 3 indicates that the groups of variables associated with these two factors can largely explain the differences among the four main mapable rock types in the Ropes deposit. Variation in CaO content, from factor 3, and CO_2, as well as compositional differences possibly attributable to the original rock type, factor 1, account for the differences between the group 1 and group 2 rocks. The greater values of factor 1 for some of the carbonate - quartz - chlorite rocks relative to the carbonate - talc rocks and serpentinitic peridotite may reflect addition of the components influencing factor 1 to the carbonate - quartz - chlorite rock from the quartz - sericite - chlorite rocks. The large positive and negative vertical spread relative to factor 5 for some of the

Figure 3-9. Factor plot using 19 element major and trace analyses of whole rocks from Ropes deposit, illustrating division into two groups based on Factor 3 (positively influenced by abundances of SiO_2, Al_2O_3, K_2O, and TiO_2, negatively influenced by abundances of MgO, CaO, MnO, LOI, and CO_2) versus Factor 1 (positively influenced by abundance of CaO, negatively influenced by abundance of H_2O).

See text for discussion.

Rock types on plot are designated as:
A = quartz - sericite - chlorite rock
B = carbonate - quartz - chlorite rock
T = carbonate - talc rock
P = serpentinitic peridotite



3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
Factor 3
-2 0
-1.0
0.0
1.0
2.0
Factor 1
B
T
P
A

quartz - sericite - chlorite rocks suggests that Na_2O was mobile in the Ropes deposit (appendix C-3).

3.3.4 Distribution of Rare Earth Elements

Rare earth elements are generally less mobile than many major element components of a rock during alteration. Two distinct groups of rocks are recognized on a chondrite normalized plot (figure 3-10, table 3-3):

(1) Quartz - sericite - chlorite rock from within and 300 meters east of the Ropes main ore zone and dacite tuff from west and northwest of the deposit have steep negative overall rare earth slopes, steep light rare earth slopes, and flat heavy rare earth slopes. Rare earth patterns match those for tonalites and subduction related dacite and andesite derived from melting of an eclogite or mafic granulite source area (Hawkesworth and others, 1977).

(2) Serpentinitic peridotite and carbonate - quartz - chlorite rock from peripheral to the deposit, as well as a lense of carbonate - quartz - chlorite rock within quartz - sericite - chlorite rock 300 m

Figure 3-10. Chondrite normalized rare earth element plot for rocks from the Ropes deposit, indicating division into two main groups of rocks. Inferred protoliths are dacite and peridotite. Samples include:

1.) quartz - sericite - chlorite rock from south of main ore zone,

2.) quartz - sericite - chlorite rock from main ore zone, with 2 g/tonne Au,

3.) quartz - sericite - chlorite rock from 250 m east of main ore zone,

4.) feldspar porphyritic dacite tuff from 200 m west of main ore zone,

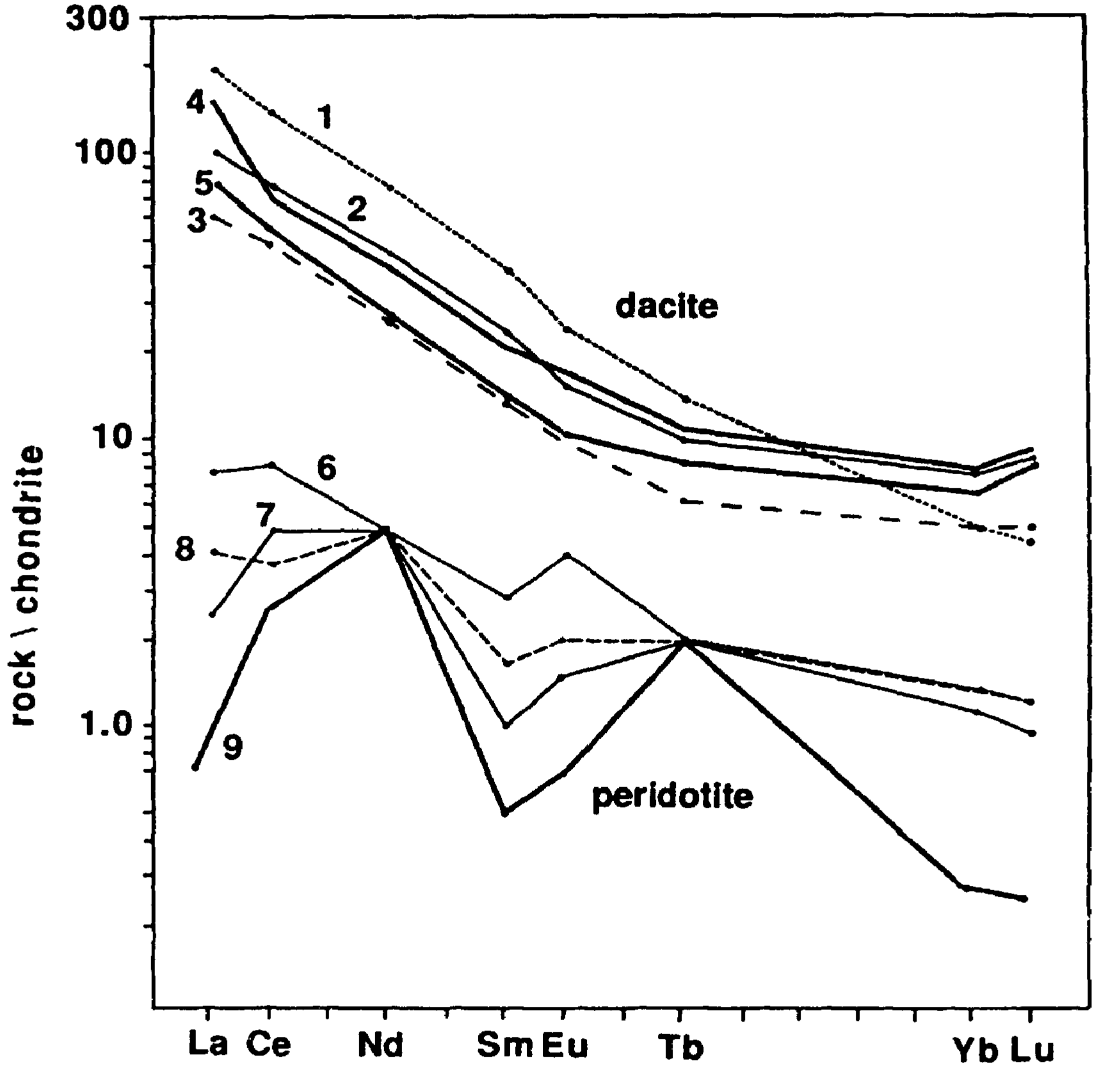
5.) feldspar porphyritic dacite tuff from 400 m northwest of main ore zone,

6.) carbonate - quartz - chlorite rock from 250 m east of main ore zone,

7.) serpentinitic peridotite, with relict cumulate texture after olivine from 20 m north of 530 level,

8.) carbonate - quartz - chlorite rock from 10 m south of 530 level, and

9.) serpentinitic peridotite with relict cumulate texture after olivine from 45 m north of main ore zone.



CHONDRITE NORMALIZED RARE EARTH PLOT

Table 3-3. Chondrite normalized rare earth element ratios

Comment	Sample #	Overall Slope	Overall Slope	Light Rare Earths	Heavy Rare Earths	
		(La/Lu)cn	(La/Yb)cn	(La/Sm)cn	(Tb/Lu)cn	(Eu/Sm)cn
1	RISO-48	44.98	40.99	4.98	3.08	0.6
2	RISO-19	12.13	13.9	4.29	1.14	0.63
3	RS-26-126	12.88	13.01	4.57	1.24	0.72
4	SLU-3-168	12.19	13.41	4.95	1.18	0.88
5	MSL-28	8.85	11.74	4.9	0.98	0.66
6	RS-26-166	6.41	6.11	2.77	1.65	1.41
7	RISO-46	2.73	2.2	2.57	2.2	1.54
8	RISO-49	3.33	3.07	2.48	1.65	1.17
9	RS-17-221	2.06	1.88	1.23	6.58	1.33

1 - quartz-sericite-chlorite rock from south of main ore zone
2 - quartz-sericite-chlorite rock from main ore zone, 2g/tonne Au
3 - quartz-sericite-chlorite rock from 250 m east of main ore zone
4 - feldspar porphyritic dacite tuff from 200 m w of main ore zone
5 - feldspar porphyritic dacite tuff from 400 m nw of main ore zone
6 - carbonate-quartz-chlorite rock from 250 m east of main ore zone
7 - serpentinitic peridotite from 20 m north of main ore zone
8 - carbonate-quartz-chlorite rock from 10 m south of 530 level
9 - serpentinitic peridotite from 45 m north of main ore zone

Chondritic values recommended by Neutron Activation Services Lab

La	0.315
Ce	0.813
Nd	0.597
Sm	0.192
Eu	0.072
Tb	0.049
Yb	0.0323

east of the Ropes main ore zone, have flat overall rare earth slopes, and low, erratic light rare earth slopes. The low, flat overall rare earth patterns match those reported in the literature for olivine rich ultramafic rocks, but erratic light rare earth patterns, especially with respect to La, Ce, and Sm indicate that the light rare earths possibly were differentially mobilized to a minor extent during alteration of the ultramafic rocks. Because of low initial rare earth contents in dunites and harzburgites, reported concentrations of rare earth elements may be particularly susceptible to analytical error.

Analysis for Ce alone would be an effective reconnaissance method of separating unknown samples into one of these two groups of rocks, because chondrite normalized Ce abundances differ by nearly an order of magnitude between the two groups (figure 3-10).

3.3.5 Trace Element Correlation with Gold Abundance

Thirty eight rock samples from the Ropes deposit, including 27 quartz - sericite - chlorite rocks and 11 carbonate - quartz - chlorite rocks, were analyzed for selected major and trace elements listed in appendix D-1. Only Ag and Sb abundances have a strong positive correlation with Au concentration.

3.3.6 Summary of Chemical Composition of Rocks

Abundances of rare earth elements along with abundances of other less mobile trace elements, and factor plots utilizing abundances of major and trace elements in whole rocks indicate two main protoliths in the deposit: (1) Dacite, with minor andesite and basalt. These are now quartz - sericite - chlorite rock, and (2) Peridotite. This is now serpentinitic peridotite, carbonate - talc rock, and carbonate - quartz - chlorite rock. Concentrations of MgO > 14 wt.%, Cr > 600 ppm, and Ni > 1000 ppm in serpentinitic peridotite, carbonate - talc rock, and carbonate - quartz - chlorite rock suggest that these rocks share a common ultramafic parentage. Greater abundances of CaO and CO_2 in the carbonate - talc rock and carbonate - quartz - chlorite rock relative to the other rocks indicate that the edges of the serpentinitic peridotite are more carbonate - rich than either the quartz - sericite - chlorite rock or the interior of the serpentinitic peridotite. A possible explanation for these maxima is the migration of CaO and CO_2 outward by diffusion from a center of fluid flow in the quartz - sericite - chlorite rock.

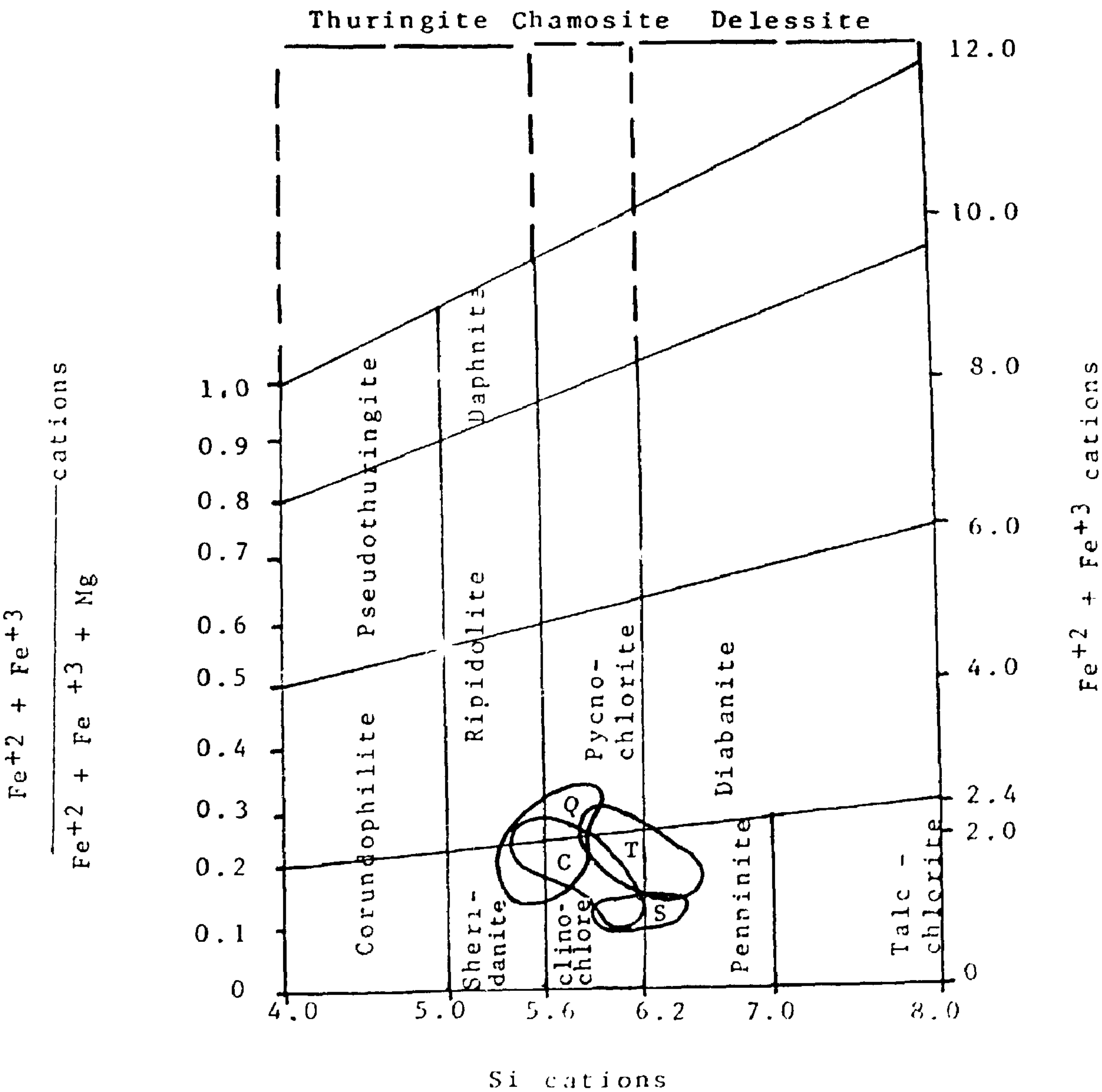
Although the serpentiniitic peridotite, carbonate - talc rock, and carbonate - quartz - chlorite rock have similar less mobile trace element and rare earth distributions, they are zoned systematically with respect to major oxides (appendix C-3, plot of factor 1 versus factor 3) and therefore are chemically distinct, as well as field mapable, rock types.

3.4 Composition of Minerals in Ropes Deposit

3.4.1 Chlorite

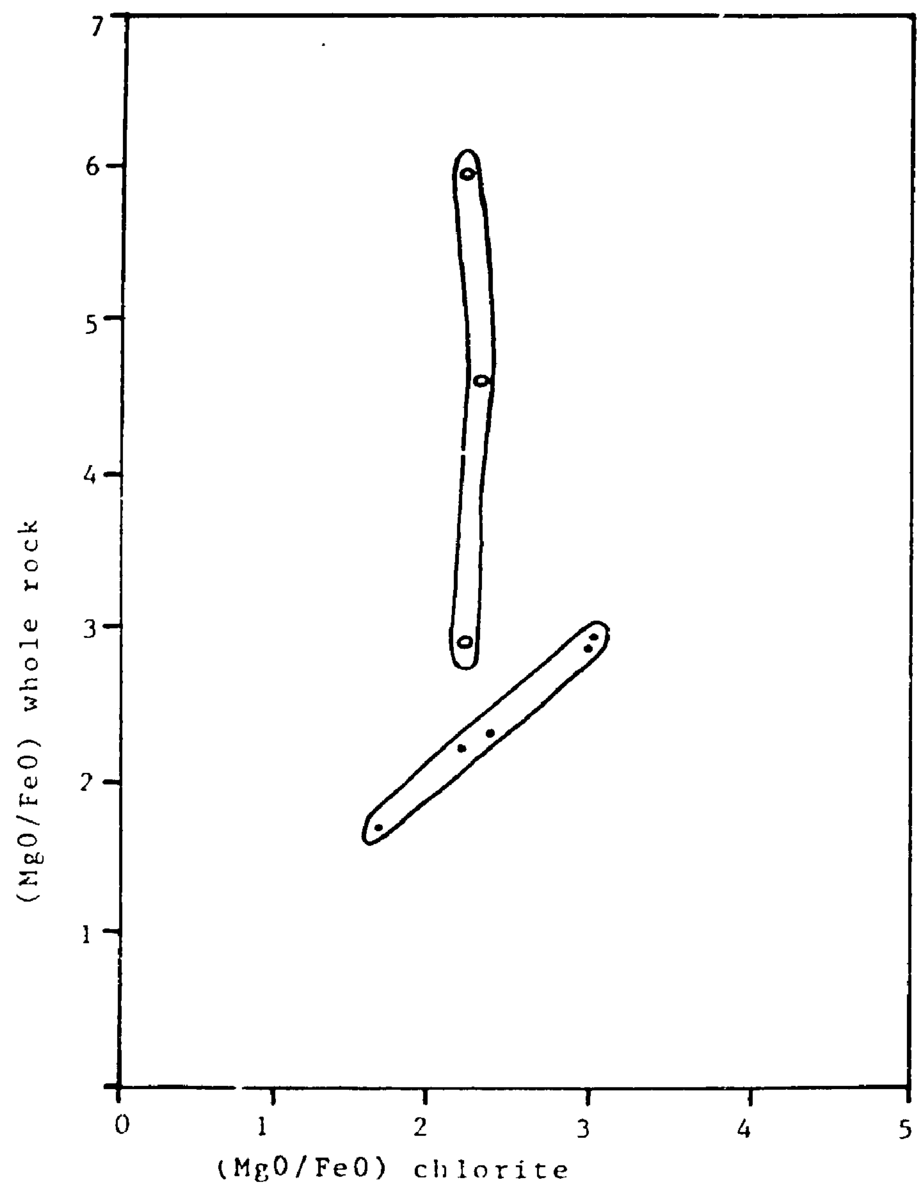
Chlorite is in nearly all rock types, but its composition and abundance are variable. It has decreasing Mg/(Mg+Fe) from serpentinitic peridotite to quartz - sericite - chlorite rock, and increasing Al/(Al+Si), and decreasing Cr toward the quartz - sericite - chlorite rocks (appendix E-1) . It ranges from clinochlore and penninite in the serpentinitic peridotite and carbonate - talc rocks, to sheridanite, ripidolite, and pycnochlorite in the quartz - sericite -

Figure 3-11. Compositions of chlorite in rocks from the Ropes deposit, on the basis of 22 oxygen in structural formula. Analyses by electron microprobe. Compositional fields for chlorite in major rock types of the Ropes deposit are designated: Q = quartz - sericite - chlorite rock, C = carbonate - quartz - chlorite rock, T = carbonate - talc rock, S = serpentinitic peridotite.


Thuringite Chamosite Delessite
Pseudothuringite
Daphnite
Ripidolite
Pycno-chlorite
Diabanite
Corundophilite
Sheri-danite
clino-chlore
Penninite
Talc - chlorite
Q
C
T
S
$\frac{Fe^{+2} + Fe^{+3}}{Fe^{+2} + Fe^{+3} + Mg}$ cations
$Fe^{+2} + Fe^{+3}$ cations
Si cations
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
4.0
5.0
5.6
6.2
7.0
8.0
12.0
10.0
8.0
6.0
4.0
2.4
2.0
0

chlorite rocks (figure 3-11). Chlorite in the carbonate - quartz - chlorite rocks spans the range from penninite to ripidolite. Chlorite in the serpentinitic peridotite and carbonate - talc rocks is Fe-poor and Si-rich relative to chlorite in the quartz - sericite - chlorite rock. MgO/FeO of chlorite is strictly related to MgO/FeO of the whole rock in the quartz - sericite - chlorite rock, but is at a constant MgO/FeO ratio within the carbonate - quartz - chlorite rock, possibly because MgO can also be accommodated in dolomite in the latter rock type (figure 3-12). Chlorite in veinlets and on foliations is not significantly different in composition from chlorite in the groundmass of the rock (appendix E-1), except where it surrounds fractured chromite in carbonate - talc rock and serpentinitic peridotite it is Cr rich (plate 3-18b). In a previous study, clinochlore has been interpreted as two structural types: early fine grained lower ordered Ib chlorite relatively enriched in Mg and Si in the rock matrix and on foliations, and later porphyroblastic higher ordered IIb chlorite relatively higher in Fe and Al (Shepeck and Bornhorst, 1984).

Figure 3-12. An example of variation of MgO/FeO in whole rock versus MgO/FeO in chlorite for 5 quartz - sericite - chlorite rocks (solid circles) and 3 carbonate - quartz - chlorite rocks (open circles) from the Ropes deposit. MgO and FeO used to calculate ratio are in wt.%.


7
6
5
4
3
2
1
0
1
2
3
4
5
(MgO/FeO) whole rock
(MgO/FeO) chlorite

3.4.2 Sericite

Sericite is restricted mostly to quartz - sericite - chlorite rock and is minor in carbonate - quartz - chlorite rock, where these two rocks are in contact. The sericite is an impure celadonitic muscovite, intermediate in composition between muscovite, K (Al_4) $(Al_2Si_6O_{20})$ $(OH)_2$, and phengite, K $(Mg_{.5}$ $Fe_{.5}$ $Al_3)$ $(AlSi_7O_{20})$ $(OH)_2$, with Fe and Mg contents of as much as several weight percent each. The sum of Mg+Fe cations in the sericite structural formula, on the basis of 22 oxygens, is between 0.4 and 1.2 cations, centered at 0.6 cations, although a few samples have up to 2.4 Fe+Mg cations (figure 3-13). There is no consistent transition in composition of sericite in rocks of the Ropes deposit. No differences in composition were detected between sericite internal to the sericite pseudomorphs after feldspar phenocrysts, sericite in the foliated groundmass, or sericite as coarser platelets which cut across the foliation. Intra - sample compositional variability for sericite was not determined to be significantly different from the inter - sample variability (appendix E-2), possibly largely because sericite occurs at Ropes almost exclusively in the relatively thin trend of quartz - sericite - chlorite rock. Ti content averages 0.03 Ti cations on the basis of 22

Figure 3-13. Mg + Fe cations in sericite from quartz - sericite - chlorite rocks of the Ropes deposit illustrating celadonitic muscovite composition. Based on 22 oxygen in structural formula. Analyses by electron microprobe.

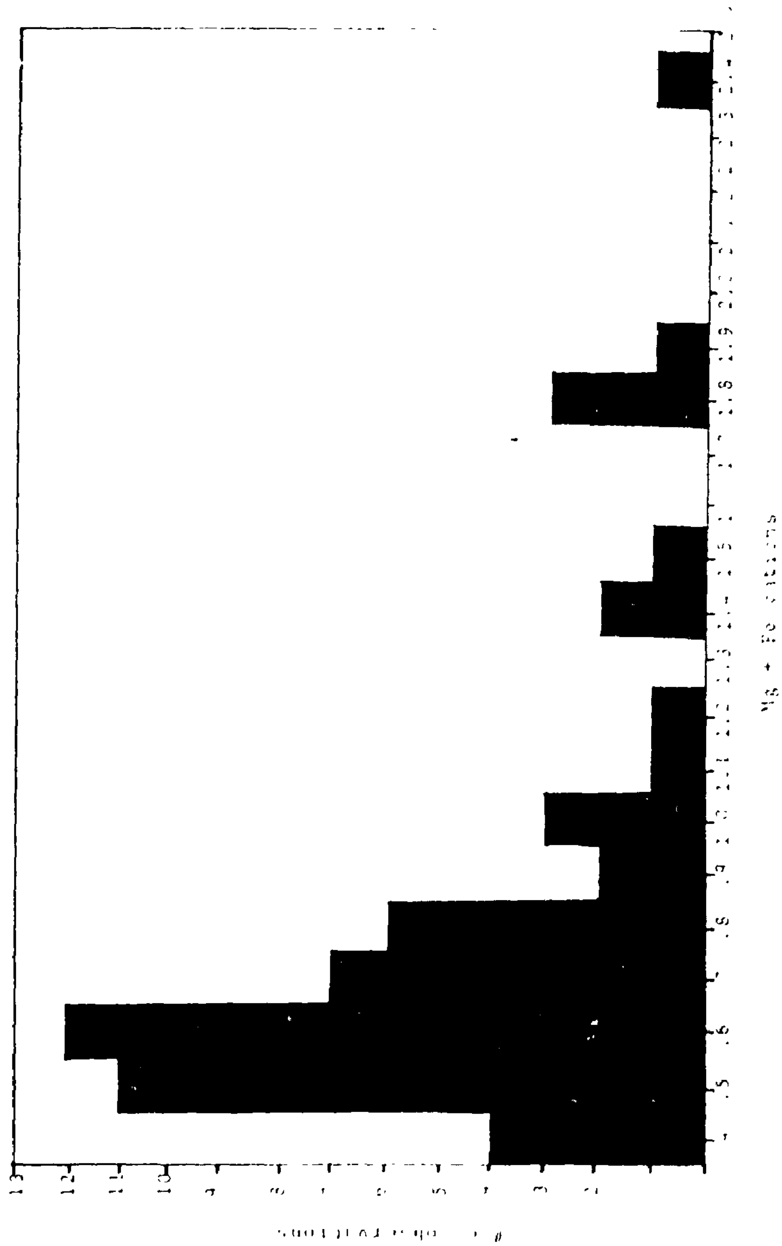
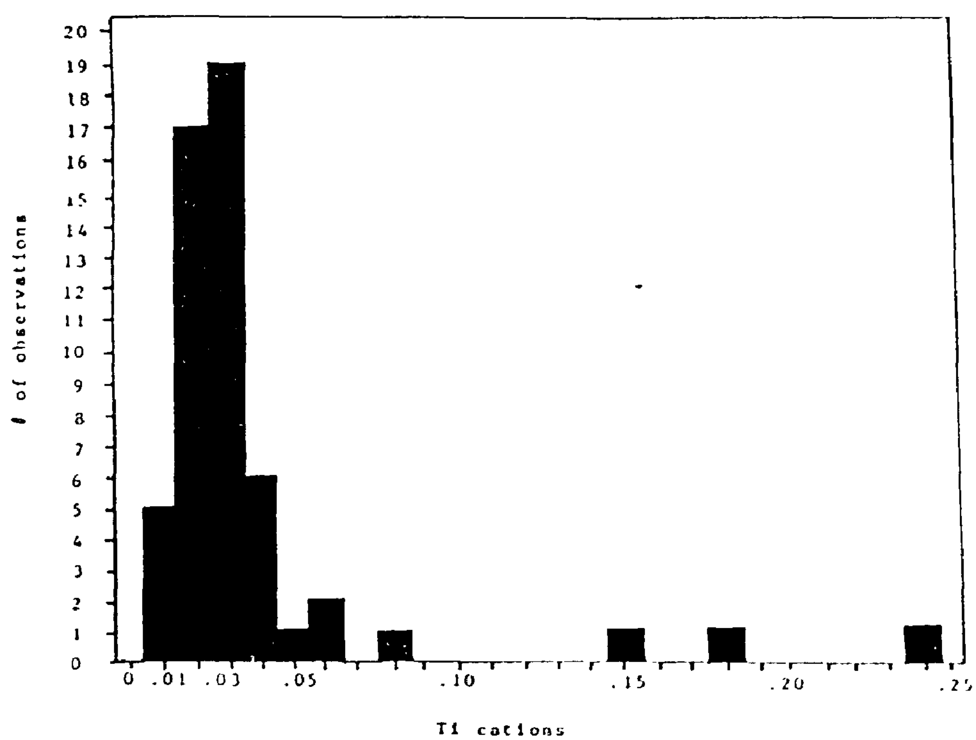


Figure 3-14. Ti cations in sericite from quartz - sericite - chlorite rocks of the Ropes deposit, indicating minor abundance of Ti in the sericite. Based on 22 oxygen in structural formula. Analyses by electron microprobe.



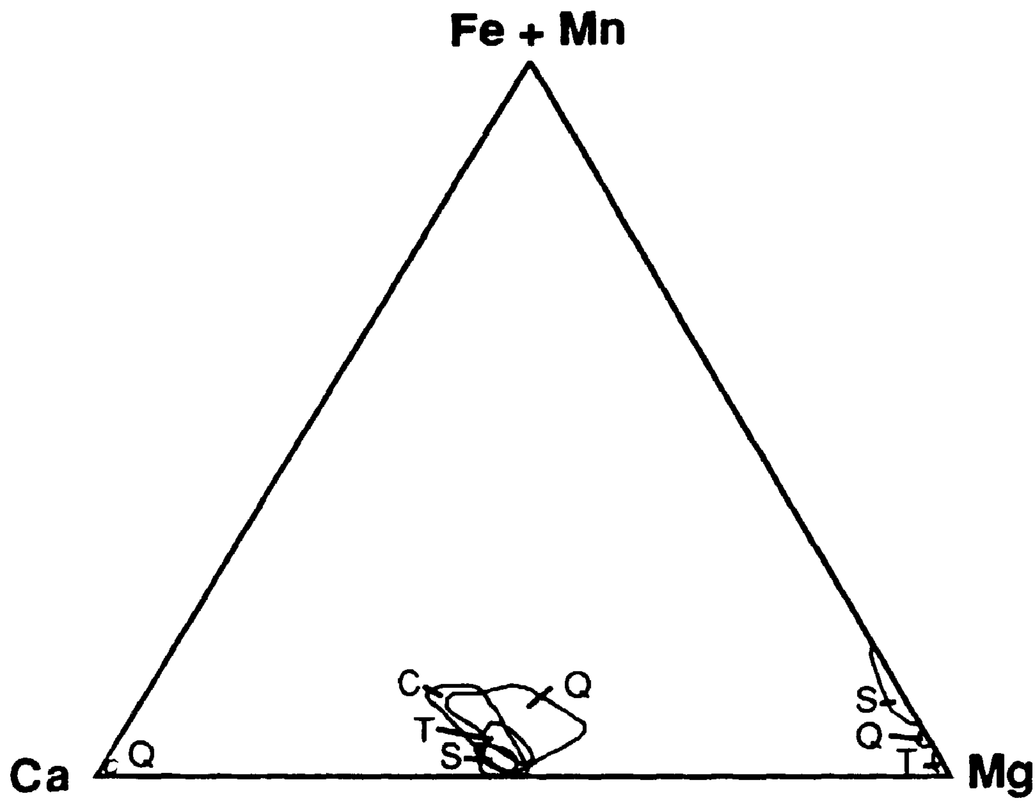
# of observations
Ti cations

oxygen (figure3-14), and its abundance in sericite does not correlate with samples having greater Au abundance, whereas sericite from some gold deposits is reported to have a marked increase in Ti within ore (R. L. Barnett, University of Western Ontario, personal communication). Both very fine grained sericite internal to the pseudomorphs after feldspar and the slightly coarser sericite in the matrix were determined to be 2m1 structural type in a previous study. (Shepeck and Bornhorst, 1984).

3.4.3 Carbonate Minerals

Carbonate minerals are common to all rocks (appendix E-3). Ferroan dolomite is only a minor component in quartz - sericite - chlorite rock, but is a major component in the other three major rock types. Calcite is minor in quartz - sericite - chlorite rock and absent in the other three major rock types. Magnesite is a major component of the serpentinitic peridotite and the carbonate - talc - rock. Magnesite is subordinate to ferroan dolomite in the serpentinitic peridotite and carbonate - talc rock. Several carbonate mineral species occur in any given rock sample. Dolomite is least Fe rich in the serpentinitic peridotite, slightly more Fe rich in the

Figure 3-15. Cation proportions in carbonate minerals in rocks of the Ropes deposit. Analyses by electron microprobe. Compositional fields for carbonate minerals in the major rock types are designated: Q = quartz - sericite - chlorite rock, C = carbonate - quartz - chlorite rock, T = carbonate - talc rock, S = serpentinitic peridotite.



CARBONATE MINERALS COMPOSITION
CATION PROPORTIONS

carbonate - talc rocks, and has a wider range of compositions which extend to even more Fe rich varieties in the quartz -sericite - chlorite rock and carbonate - quartz - chlorite rock (figure 3-15).

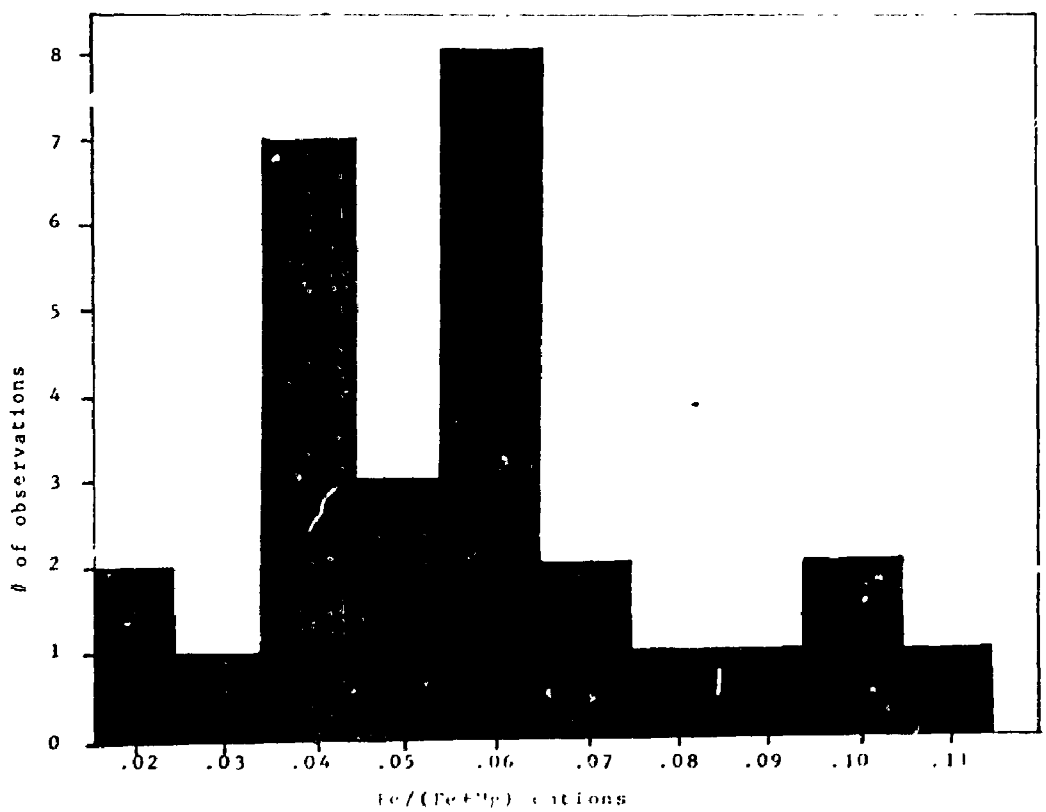
3.4.4 Talc

Talc is in serpentinitic peridotite and carbonate - talc rock, and to a lesser extent in carbonate - quartz - chlorite rock (appendix E-4). Its composition varies within relatively narrow limits, from essentially pure Mg - talc to talc with an Fe/(Fe+Mg) cation ratio of up to 0.11, centered at 0.05. (figure 3-16). Talc increases in iron content away from serpentinitic peridotite through the carbonate - talc rock and carbonate - quartz - chlorite rock toward quartz - sericite - chlorite rock, but is absent in the quartz - sericite - chlorite rock itself.

3.4.5 Serpentine

Serpentine is only in the serpentinitic peridotite, where it is a major constituent, as radiating clots which appear to pseudomorph primary cumulate olivine crystals and as oriented laths apparently

Figure 3-16. Fe/(Fe +Mg) cation ratio in talc for rocks of the Ropes deposit. Analyses by electron microprobe.



# of observations
0
1
2
3
4
5
6
7
8
.02
.03
.04
.05
.06
.07
.08
.09
.10
.11

parallel to former cleavage directions in subordinate pseudomorphed pyroxene (appendix E-5).

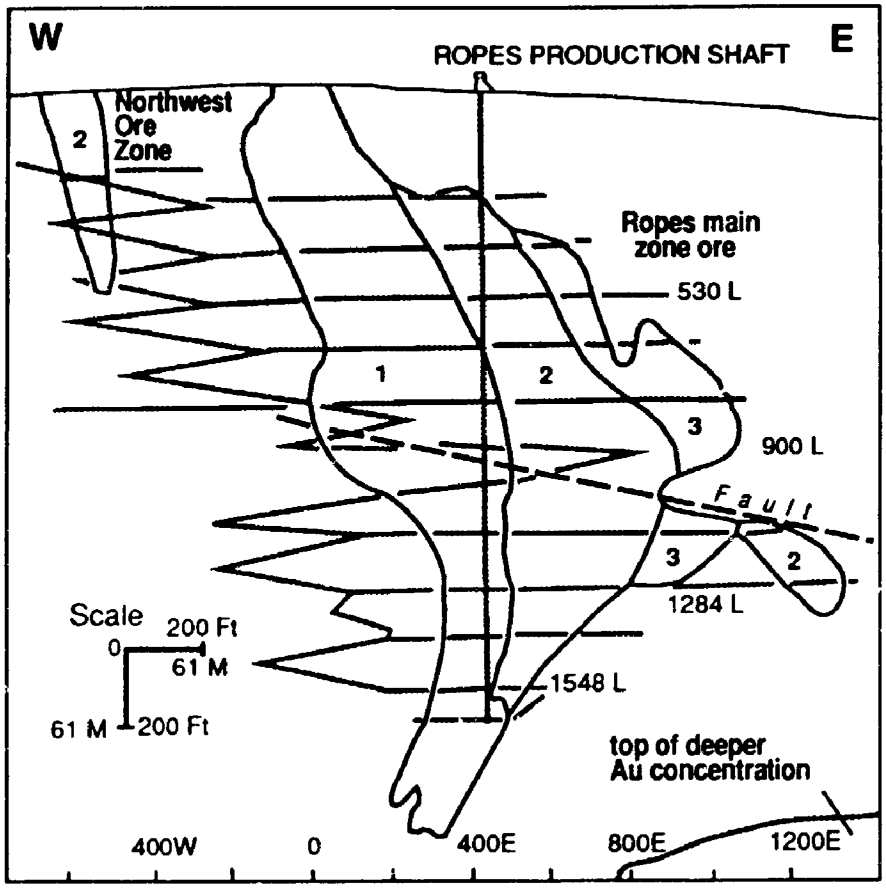
3.4.6 Chromite

Chromite is a minor mineral in the serpentinitic peridotite, carbonate - talc rock, and carbonate - quartz - chlorite rock. It is very fine round euhedral grains, mostly on chlorite - bearing foliations and generally surrounded by Cr rich chlorite. The chromite has a wide range of Al and Fe content among different samples (appendix E-6).

3.5 The Orebodies

The Ropes deposit is 2.8 million tonnes with 3.71 g/tonne Au, including past production and geologic reserves. There are two main types of ore: 1.) Ninety five percent of the ore is dispersed pyrite with gold in quartz - sericite - chlorite rock. This ore has several subtypes with varying proportions of quartz, sericite, chlorite, and pyrite (figure 3-17). 2.) Five percent of the ore is banded auriferous quartz veins with saccharoidal texture containing tetrahedrite,

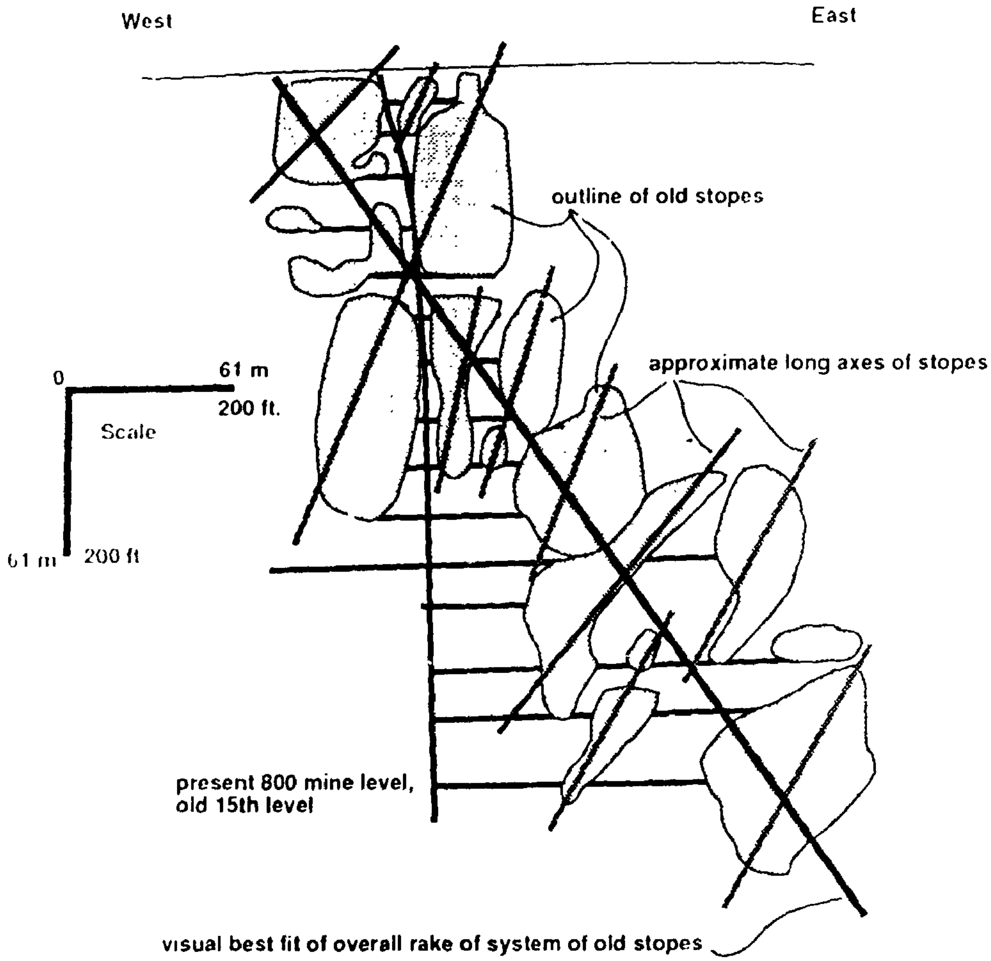
Figure 3-17. Vertical long section of the Ropes gold deposit in the 080° plane, with subtypes of gold ore.



Subtypes of gold ore with dispersed pyrite:

1	QUARTZ - SERICITE ROCK, WITH GRAY QUARTZ LENSES
2	QUARTZ - SERICITE - CHLORITE ROCK, GOOD Au : PYRITE CORREi.ATION
3	QUARTZ - CHLORITE - PYRITE ROCK

Figure 3-18. Vertical long section in the 080° plane illustrating configuration of stopes developed in late 1800's, which followed auriferous quartz veins and en echelon groups of these veins at the south side of the Ropes main ore zone. Old 15th level is equivalent to 800 level in the present Ropes mine. Long axes of individual stopes rake steeply west. Visually estimated line connecting the midpoints of major old stopes rakes steeply east.



Long Section of old stopes developed in late 1800s on auriferous quartz veins at south side of Ropes deposit (viewed in 080 degree plane)

pyrite, galena, and chalcopyrite. It is at or near the south side of the deposit (figure 3-18; plate 3-12b, c, d).

3.5.1 Dispersed Pyrite With Gold in Quartz - Sericite - Chlorite Rock

The Ropes main ore zone is steeply dipping, 335 m in maximum strike length, 12 m in average thickness, and 600 m in known down - dip extent (figure 3-2, 3-17). It is dispersed pyrite with gold in quartz - sericite - chlorite rock, with only minor quartz veins.

3.5.1.1 Subtypes of Gold Ore With Dispersed Pyrite

The Ropes main ore zone is divided longitudinally into three ore subtypes (figure 3-17.; plate 3-12a), from west to east, in long section, 1.) Subtype 1 is light gray to pale green, siliceous quartz - sericite rock, containing minor lenses of light gray microcrystalline quartz rock with pyrite - tetrahedrite - chalcopyrite - galena. Pyrite abundance does not correlate with gold abundance. Subtype 1 is in interdigitating contact with barren quartz - sericite - chlorite and carbonate - quartz - chlorite rocks to the west, and is in gradational contact to the east with subtype 2. Average gold

Plate 3-12. Gold ore types from the Ropes deposit.

A.) subtypes of gold ore characterized by dispersed pyrite with gold in quartz - sericite - chlorite rock. Scale bar is in cm. Ore is zoned from west to east into three subtypes:

1.) Subtype 1. Light gray to pale green siliceous quartz - sericite rock

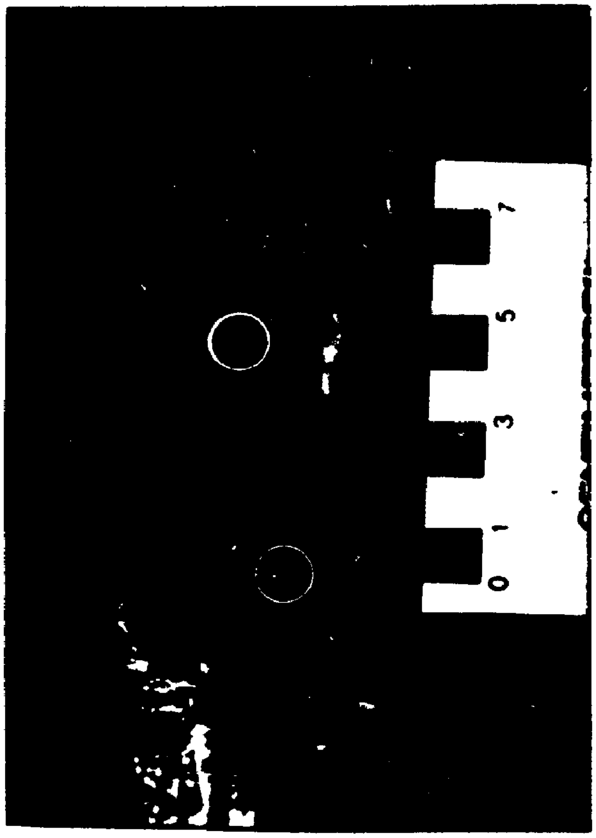
2.) Subtype 2: Light green quartz - sericite - chlorite rock with fine grained dispersed auriferous pyrite

3.) Subtype 3: Dark green quartz - chlorite - pyrite rock with consistently large content of fine grained pyrite

B.) Layered auriferous quartz vein in quartz - sericite - chlorite rock, Ropes deposit. Hammer is 30 cm.

C.) Layered auriferous quartz vein from the Ropes deposit, Lower Secondary drift. Irregular dark colored patches in light colored quartz on right side of specimen are tetrahedrite. Elongate dark colored lenses at far right and left - center of specimen are septa of foliated quartz - sericite - chlorite rock. Scale bar at lower right in in cm.

D.) Thin section photomicrograph of quartz from auriferous vein with mortar texture at edges of quartz grains, and undulose extinction in quartz.



A

B

C

D

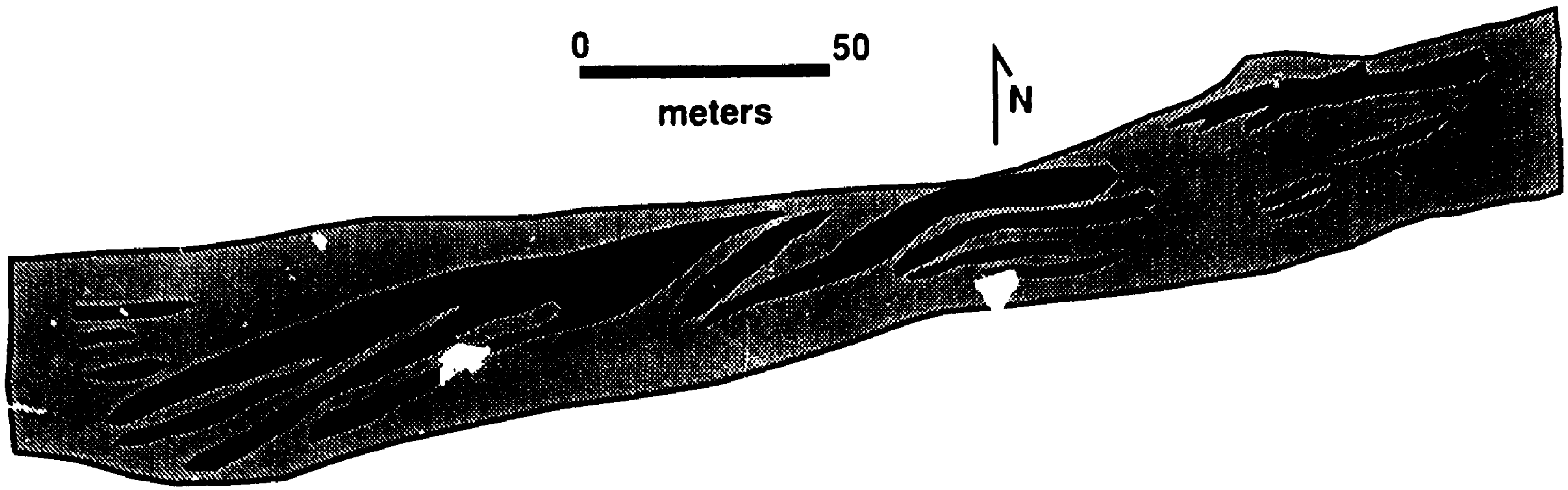
concentration is 6.8 g/tonne. 2.) Subtype 2 is light green quartz - sericite - chlorite - pyrite rock with a positive correlation between fine grained pyrite content and gold abundance. Subtype 2 is the thickest part of the ore zone and, therefore, the most volumetrically important. It is in relatively sharp contact to the east with subtype 3. Gold concentration in various parts of subtype 2 ranges from 2.6 g/tonne to, rarely, 6.2 g/tonne, 3.) Subtype 3 is dark green quartz - chlorite - pyrite rock with a consistently large content of fine grained pyrite. It is in sharp contact with barren quartz - sericite - chlorite rock to the east. The average Au concentration is 10.3 g/tonne.

In long section, these subtypes are crescent shaped, concentric shells, with the convex side of each ore subtype toward the east and the concave side toward the west. The convex to the east geometry of the ore subtypes, along with an overall gradual diminishing Au abundance to the west and a sharp cutoff in Au abundance at the east, suggests that the flow vector for mineralizing fluids, relative to the present day surface, may have been upward from the southwest end of the deposit to the northeast, high grade keel.

Zones of greater than 4 g/tonne Au abundance, defined by assay, are contained centrally within the main ore zone (figure 3-3; map plate 5). The middle parts of these zones of greater than 4 g/tonne Au strike across the 080° trend of the orebody in right stepping en echelon fashion at approximately 065°, whereas their extremities have an 070° trend, thus forming a low angle sigmoidal pattern across the ore zone. This pattern is most pronounced at and below the 1152 level near the east end of the Ropes main ore zone (figure 3-19; map plate 5).

Above the 650 level, ore is separated from carbonate - quartz - chlorite rock by slightly auriferous quartz - sericite - chlorite rock, but below the 650 level the east end of the orebody is in contact with the carbonate - quartz - chlorite rock on the north (figure 3-7; map plate 5). The north side of the orebody strikes 070° and dips very steeply north whereas the contact between the quartz - sericite - chlorite rock and the carbonate - quartz - chlorite rock on the north strikes 080° and dips steeply south. Therefore, at depth, the orebody abuts the carbonate - quartz - chlorite rock contact on the north, with the east limit of the main ore zone plunging to the west at deeper levels along the line defined by the intersection of the planes

Figure 3-19. Distribution of en echelon zones of greater than 4 g/tonne gold concentration within the trend of quartz - sericite - chlorite rock on part of the 1152 level, Ropes mine. Zones of greater gold concentration follow the schistosity in right stepping en echelon fashion.



ROPES MINE 1152 LEVEL PLAN

> 4 g onne Au ore zones

quartz - sericite - chlorite rock

of the orebody and the carbonate - quartz - chlorite rock contact on the north. Below the 1284 level, the 25 to 40 m thick quartz - sericite - chlorite rock thins markedly to the east and interfingers along strike to the east with carbonate - quartz - chlorite rock. The thickest part of the quartz - sericite - chlorite rock plunges approximately 45° east and is coincident with the bend in strike of the trend of quartz - sericite - chlorite rock from 080° within the deposit back to 070° east of the main ore zone.

There are several other gold bearing bodies near the Ropes main ore zone: 1.) The northwest ore zone is a small ore zone of 101,000 tonnes with 4.6 g/tonne Au 170 m northwest of the main ore zone (Carter, 1985a, b, d) (figure 3-17; map plate 5) and is dominantly ore subtype 2. 2.) Auriferous, pyritic quartz - sericite - chlorite rock encountered in deep drilling at the Ropes deposit is separate from, and deeper to the east of, the Ropes main ore zone (Callahan Mining Corporation, 1987) (figure 3-17). Drill hole RS - 1226E - 2 intersected 25 core m (12.5 m true thickness) with 5.3 g/tonne Au in quartz - sericite - chlorite rock with 2 to 5 percent fine pyrite at 801 to 825 m drill depth (656 to 676 m vertical depth) along the north side of the quartz - sericite - chlorite rock, and 5.8

core m (4.6 m true thickness) with 16.4 g/tonne Au (4.6 g/tonne Au with assays cut to 34.2 g/tonne Au) at the south contact of the quartz - sericite - chlorite rock, from 841 to 847 core m (688 to 693 m vertical depth). The latter intersection included auriferous quartz - tetrahedrite veins at 841 to 842 m and 846 to 847 m, which contain most of the Au concentration. This deep intersection of Au concentration is identical to ore subtype 2, and has auriferous quartz-tetrahedrite veins near its south side in drill hole RS - 1226 - E - 2 and other deep drill holes.

3.5.1.2 Ore Minerals and Textures

Gold is with pyrite less than 100 microns in diameter dispersed throughout the mass of the quartz - sericite - chlorite rock (plates 3-4a, b; 3-5b c), and with this pyrite on fractures, foliations, and within and along the margins of millimeter - thick quartz veinlets. Native gold, of variable fineness, is 1 to 10 micron grains: 1.) attached to the surface of the fine grained pyrite (plate 3-13b, d), 2.) included as round blebs within fine grained pyrite (plates 3-13a, 3-14a, b), 3.) on fractures within fine grained pyrite, and 4.) at grain boundaries of fine grained quartz and sericite. In one instance, Au is apparently enclosed within a quartz grain (Honea, 1986). Minor coarse gold is on fractures in quartz veins. Silver is in electrum (plate 3-13b), and native silver is with fine pyrite (plate 3-13c), argentiferous tetrahedrite (plate 3-18a), argentiferous galena, and rare dyscrasite (plate 3-15a, b).

Pyrite is 97% of the metallic minerals followed by 1% chalcopyrite. Argentiferous galena, argentiferous tetrahedrite, tetrahedrite, sphalerite, millerite (appendix F, charts V, VI), bravoite (appendix F, chart IV), molybdenite, magnetite and rutile are present in trace amounts (tables 3-4, 3-5) (Honea, 1986; Rorick, 1986). Acanthite (plate 3-14d) and petzite (plate 3-14a) are rare (Honea, 1989). The gold is silver bearing (plate 3-13b; appendix F, chart I) and metallic Ag is gold bearing (appendix F, chart II) (Rorick, 1986). Some Au particles contain white areas with relatively equal amounts of Au and Ag (plate 3-13b; appendix F, chart III). Chalcopyrite contains intergrown Ag bearing tetrahedrite (plate 3-15a), and is locally enclosed by sphalerite (plate 3-15c). Ag bearing galena is present in trace amounts. Pyrite locally encloses galena (plate 3-16a, b, c), tetrahedrite and chalcopyrite (plate 3-14c), and acanthite and sphalerite (plate 3-14d), and rarely pyrrhotite.

Sphalerite, chalcopyrite, tetrahedrite, galena, gold, silver, and acanthite are included within pyrite in some places, but surround pyrite with similar texture in other places. Most of these minerals also are in similarly inconclusive, included versus surrounding, relationships with each other. Therefore, there is no distinct paragenetic sequence for the metallic minerals.

Sulphide minerals in auriferous, saccharoidal quartz veins include pyrite, chalcopyrite, and galena. Silver bearing minerals locally are at small irregularities on the edges of chalcopyrite grains (plate 3-15a, b) and are tetrahedrite, $(Cu, Fe, Ag)_{12}(As,Sb)_4S_{13}$ (appendix F, chart VII), which is locally rimmed by a Ag - Sb mineral, probably dyscrasite, Ag_3Sb (appendix F, chart VIII). Dyscrasite is locally rimmed by native antimony (appendix F, chart IX). Silver bearing minerals are very fine grained, 8 to 40 microns, soft, and friable, contributing to loss of Ag during milling. Not all of the tetrahedrite is silver bearing.

Plate 3-13. Gold and silver in polished sections of metallic minerals from the Ropes deposit, mounted in acryllic. Photomicrographs are 100 microns across short dimension (from Rorick, 1986).

A.) Gold included as 2 to 10 micron rounded particles in fine grained pyrite.

B.) Gold attached to pyrite; and coarse unattached Au particle which is electrum. Area labeled 1 contains relatively little Ag, area labeled 2 has relatively equal amounts of gold and silver, as determined by electron microprobe analyses.

C.) Silver included along a fracture in pyrite grain.

D.) Gold attached to pyrite.

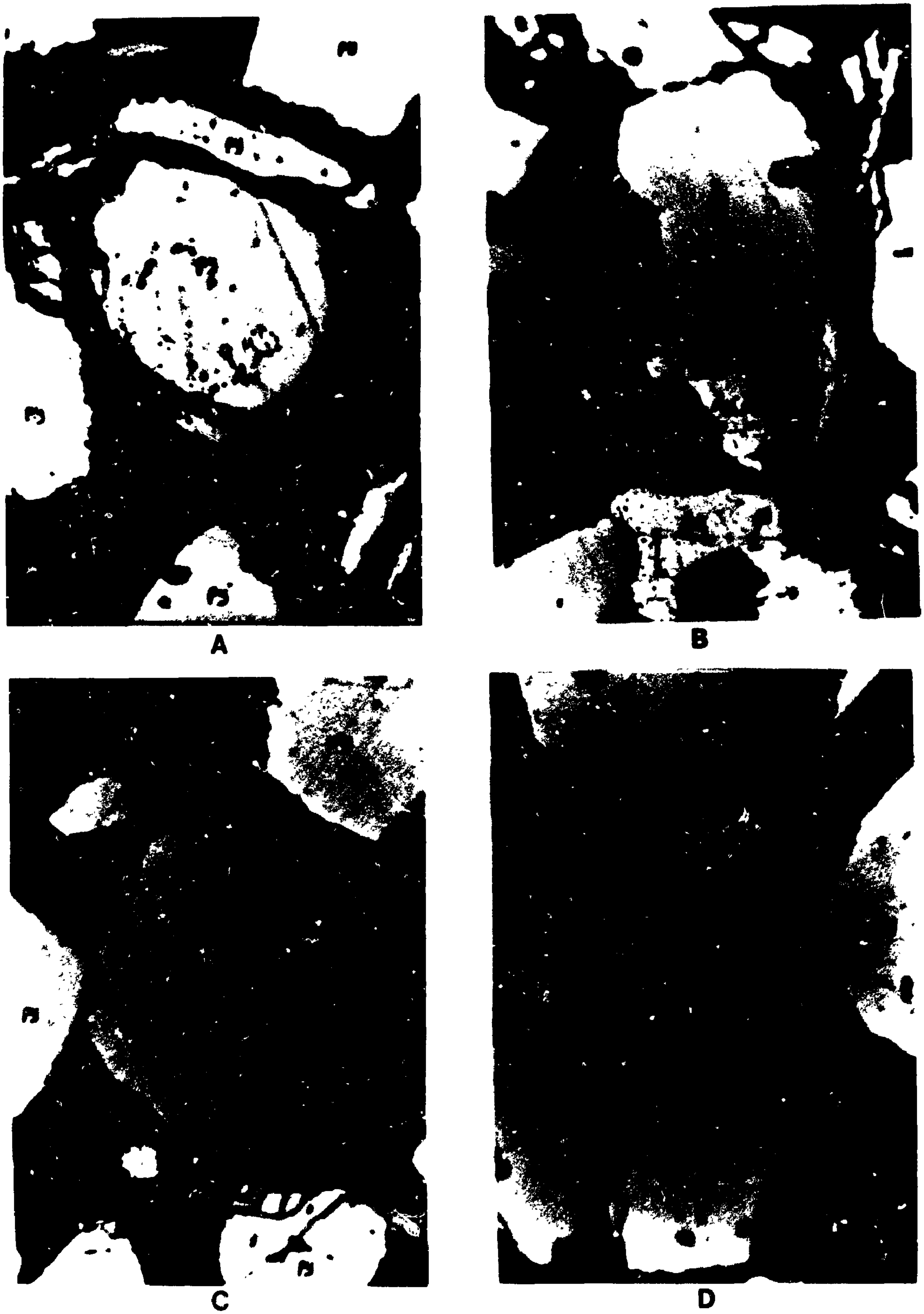

A
B
C
D

Plate 3-14. Pyrite with attached or included chalcopyrite, gold, tetrahedrite, acanthite, petzite or sphalerite: Ropes deposit, 1548 stope polished section photomicrographs, each square is 32 microns on a side (from Honea, 1989).

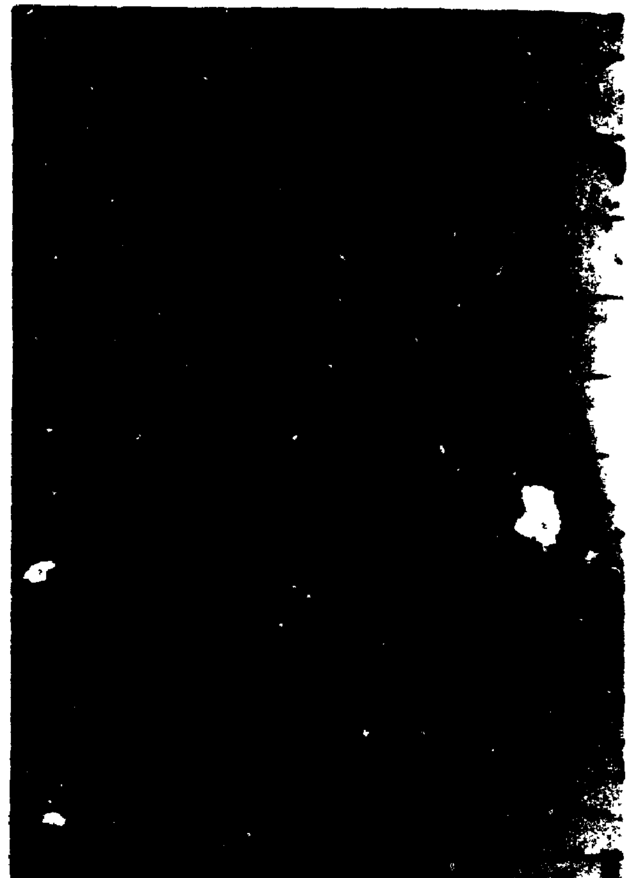
A.) Pyrite with included gold; also electrum (elec) bordered by petzite (ptz). Dark areas are silicate minerals. Polished section taken from sample of sericite - quartz rock with abundant fine pyrite.

B.) Gold particle included within pyrite. Polished section taken from sample of chlorite - sericite - quartz rock with 2 to 4 percent very fine pyrite.

C.) Pyrite with inclusion of acanthite (ac) and minor sphalerite (spy). Polished section taken from gray microcrystalline quartz rock with minor sericite.

D.) Pyrite with inclusion of tetrahedrite (tet) associated with minor chalcopyrite (cpy). Polished section taken from sericite - quartz rock with abundant very fine pyrite.

A



B

C

D

Plate 3-15. Minor ore minerals, Ropes deposit. Scanning electron microscope images. Number of microns represented by each scale bar is printed with bar along right side of photograph.

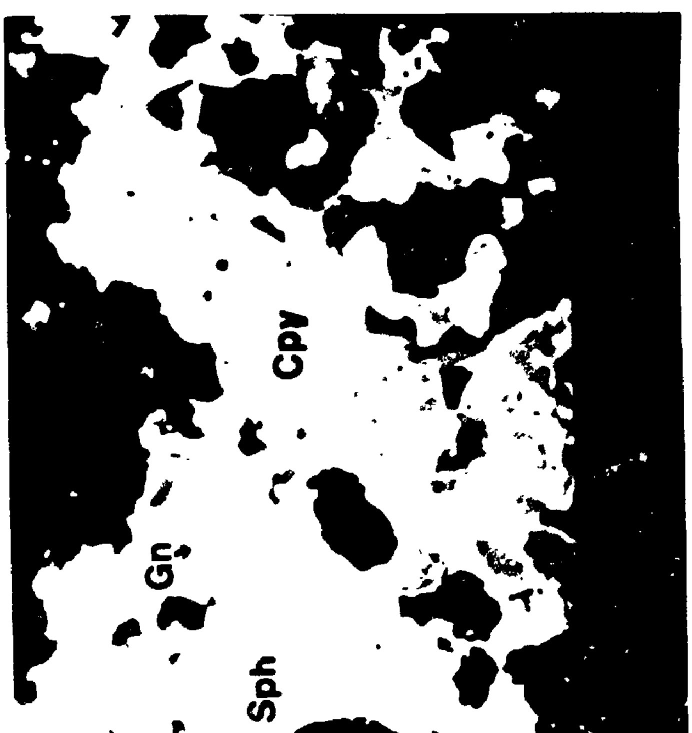
A.) Chalcopyrite (cpy); tetrahedrite (tet); and a silver - antimony mineral, probably dyscrasite (Sb-Ag) in auriferous quartz vein.

B.) Tetrahedrite (tet) rimmed by a Ag-Sb mineral in auriferous quartz vein.

C.) Sphalerite (sph), Galena (gn) and chalcopyrite (cpy) in quartz - sericite - chlorite rock.

D.) Tetrahedrite (tet), chalcopyrite (cpy), and galena (gn) in auriferous quartz vein.

A



C

D

Plate 3-16. Pyrite with included galena; minor ore minerals, Ropes deposit. Scanning electron microscope images. Number of microns represented by each scale bar is printed with bar along right side of photographs; photograph B is 100 microns across short dimension.

A.) Galena (gn) in pyrite (py) in tetrahedrite, in auriferous quartz vein.

B.) Inclusions of galena (gn) in pyrite (py).

C.) Galena (gn) in pyrite (py); enlargement of image A above.

D.) Galena (gn), chalcopyrite, and tetrahedrite in quartz - sericite - chlorite rock.

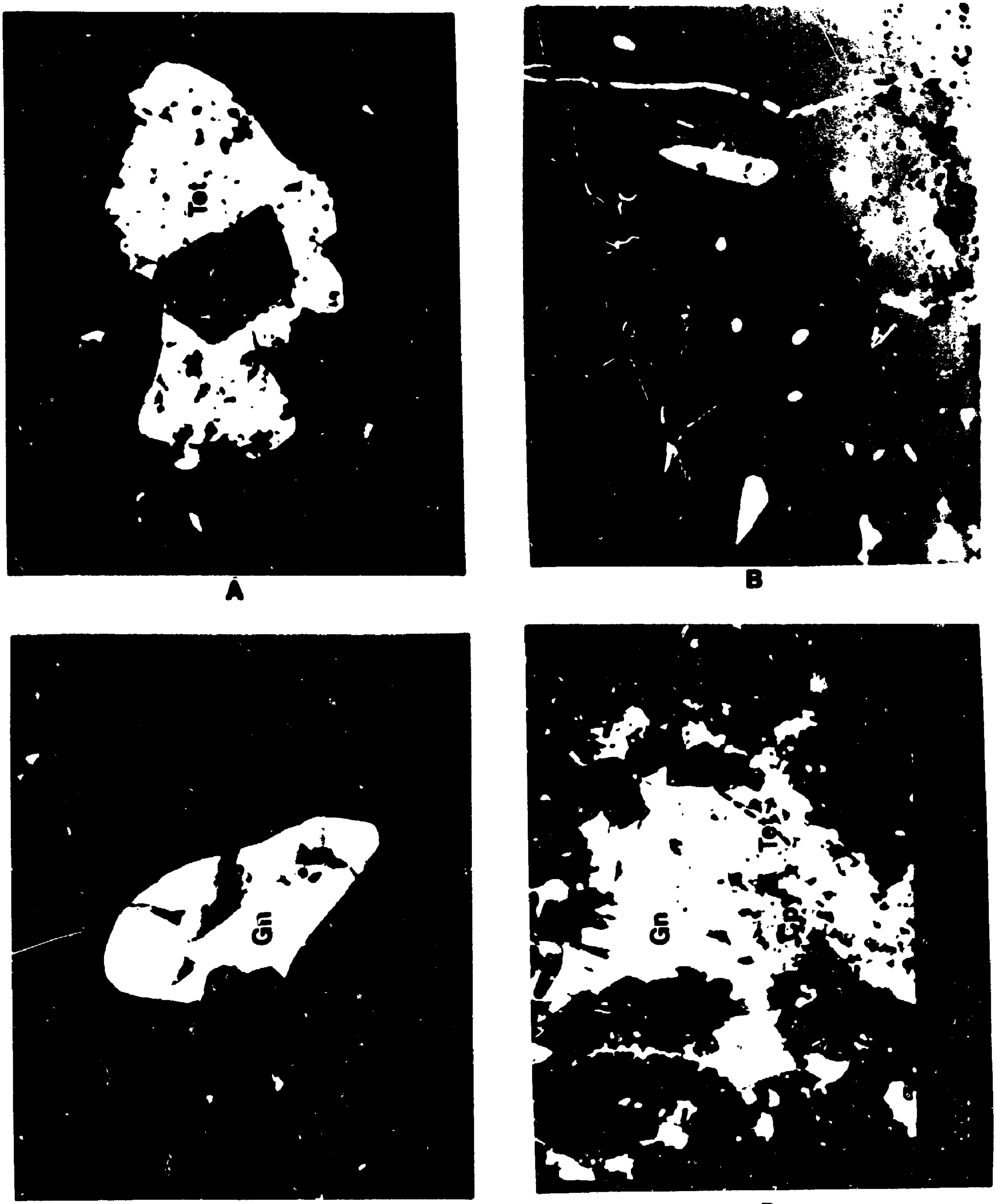

Tet.
A
B
Gn
C
Gn
Tet
D

Plate 3-17. Pyrite textures in rocks from the Ropes deposit. Scanning electron microscope images. Scale bars with number of microns per bar is at right side of each image, except that image A has 100 micron scale bar in upper right hand corner.

A.) Fine grained dispersed pyrite in quartz - sericite - chlorite rock, main ore zone

B.) Fine grained dispersed pyrite in auriferous quartz vein.

C.) Fine grained pyrite approximately 4 microns across, bottom right side of crystal is a fracture surface.

D.) Coarse grained pyrite as composite grain in quartz - sericite - chlorite rock.

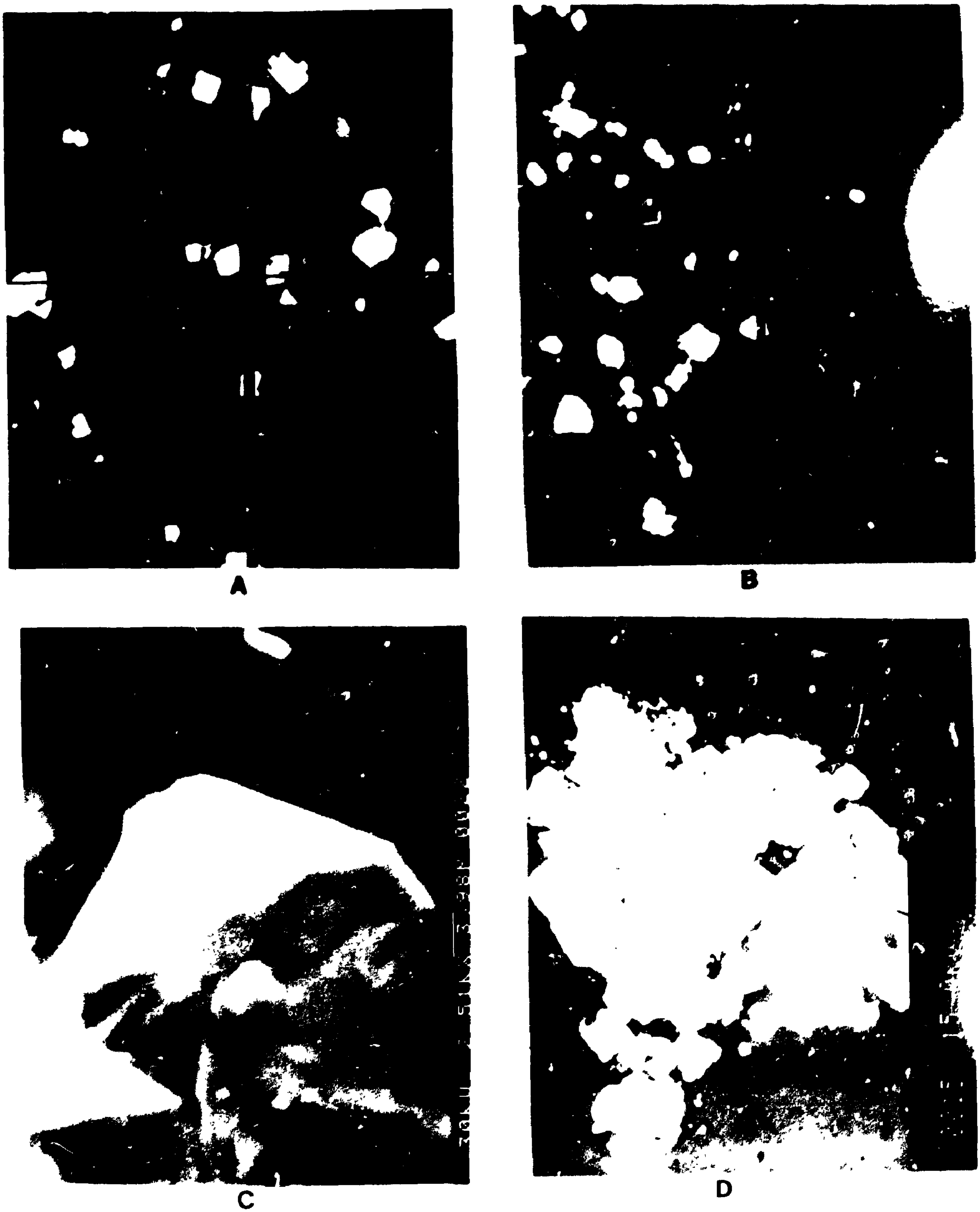

A
B
C
D

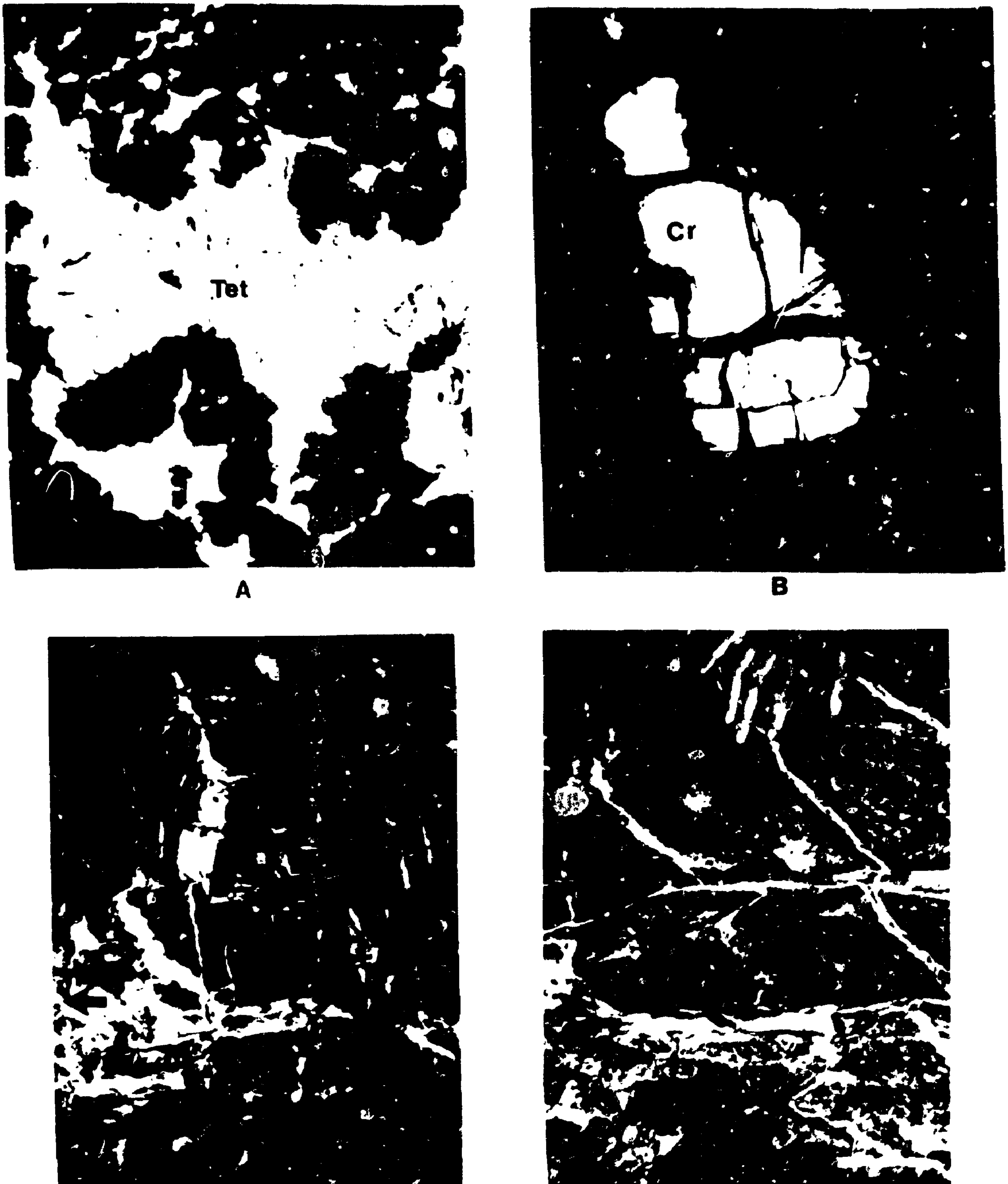
Plate 3-18.

A.) Tetrahedrite (tet) in auriferous quartz vein. Scanning electron microscope image is 200 microns across.

B.) Fractured chromite (cr) grain in carbonate - talc rock. Scale bar at right is 100 microns.

C.) Photograph of carbonate - talc rock with shallowly dipping extension veins filled by dolomite. Photograph is 2 m across short dimension. **Up direction is to left indicated by arrow at left side of photograph.**

D.) Carbonate talc rock with shallowly dipping dolomite veins offset along near vertical dolomite veins. **Up direction is to left of photograph.**



Tet
Cr
A
B
C
D

4

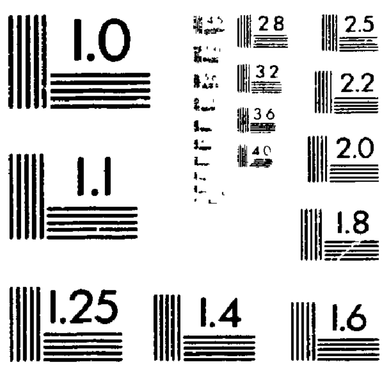


Table 3-4. Composition of Ropes mill feed (2/5/86) (Honea, 1986)

Native Au	trace
Chalcopyrite	<1%
Sphalerite	<1%
Galena	<1%
Pyrrhotite	<1%
Pyrite	3%
Rutile	<1%
Hematite	<1%
Non metallic minerals (a mixture of quartz, sericite, chlorite, and minor talc, as determined by X-ray powder diffraction)	96%

Table 3-5. Composition of Ropes flotation mill concentrate (2/15/86) (Honea, 1986).

Native Au	trace
Chalcopyrite	<1%
Sphalerite	< 1%
Galena	< 1%
Tetrahedrite	<1%
Pyrrhotite	<1%
Pyrite	44%
Magnetite	<1%
Rutile	<1%
Non metallic minerals* (major talc & minor quartz)	54%

* talc was preferentially concentrated in the flotation process at that time

3.5.1.3 Gold/Silver

The low bulk Au/Ag of 0.65 for the Ropes gold deposit (table 3-6; appendix A) differs from ratios reported for Precambrian gold quartz veins and lodes (Boyle, 1979, p. 202, table 43), which range from 1.37 to 12.5 and average about 4.2. Low Au/Ag indicates deposits which formed at relatively lower temperatures and shallower depths than deposits with high ratios, according to a world wide survey of gold deposits (Shcherbina, 1956). Au/Ag appears to decrease with increasing depth in the deposit, (figure 3-20; table 3-6) because of increasing Ag concentration with depth (figures 3-21; 3-22). This observation is based on a very limited sample size at deeper levels (table 3-6, column 2).

3.5.1.4 Metal Distribution

Both Au and Ag have continuous positively skewed log normal distributions, each with a single maximum, interpreted as indicating only one period of mineralization (Bideaux, 1982). Joint distribution of Au and Ag assays from identical assay intervals for 663 samples did not indicate any apparent correlation between Au

Table 3-6. Au/Ag for gold ore with dispersed pyrite in quartz - sericite - chlorite rock from the Ropes deposit.

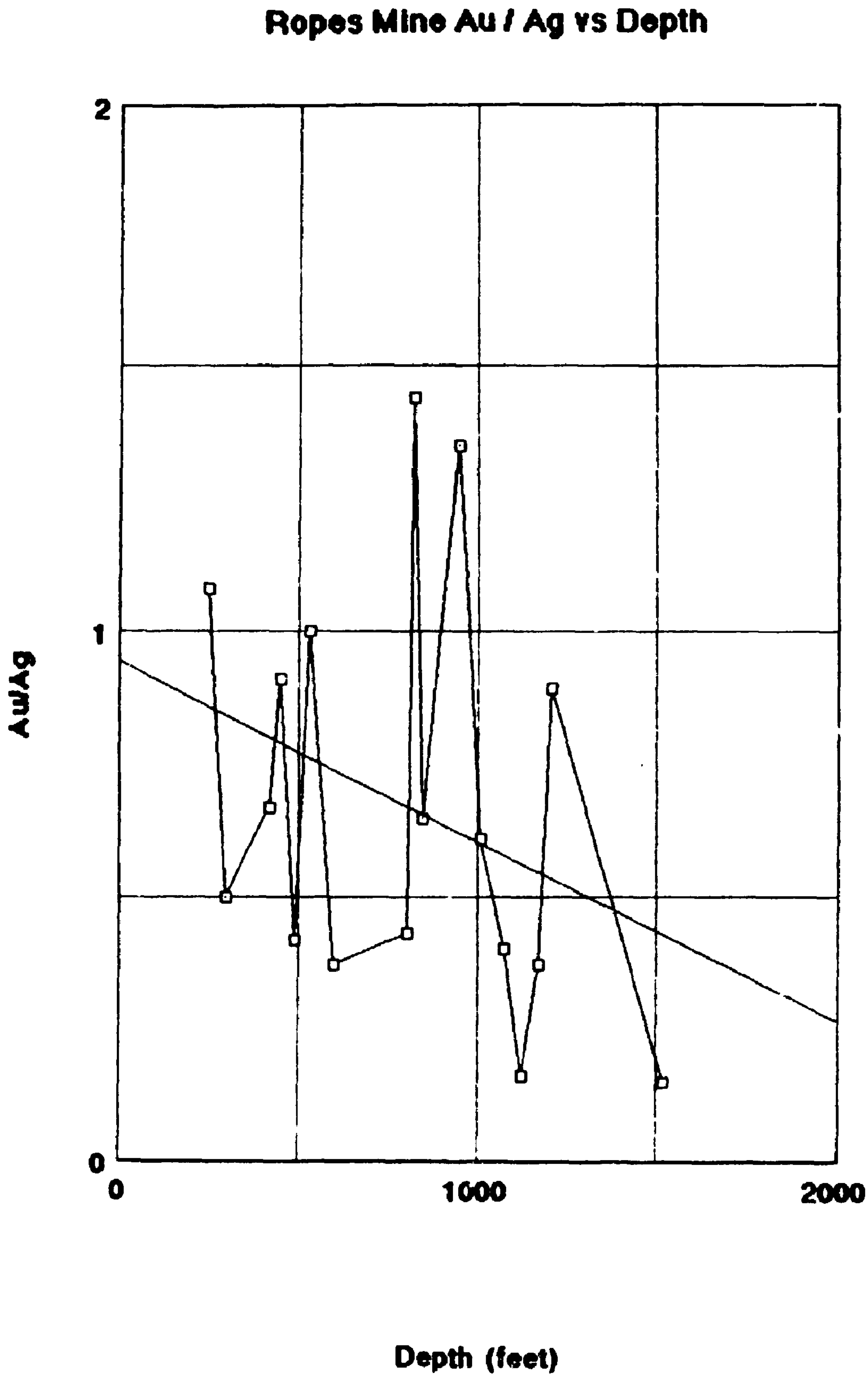
Depth m	Assayed m of core	Au(g/ tonne)	Ag(g/ tonne)	Au/Ag	
76	72.3	2.95	2.74	1.08	
91	183.0	4.62	9.25	.50	
128	191.5	4.35	6.51	.67	420 level
137	4.6	3.73	4.11	.91	
149	3.0	2.91	6.85	.42	
162	44.5	6.78	6.75	1.00	
183	43.1	12.43	33.90	.37	
244	43.2	5.53	12.96	.43	
250	6.1	3.94	2.74	1.44	
258	11.4	3.04	4.68	.65	
288	4.3	5.75	4.27	1.35	
306	12.4	3.15	5.14	.61	
326	28.9	4.48	11.18	.40	
342	18.2	6.32	39.63	.16	
357	30.5	3.42	9.25	.37	
367	32.8	3.97	4.45	.89	
462	21.5	7.20	46.52	.15	

0.65 overall weighted average

0.63 Weighted average below 420 level

0.67 Weighted average down to 420 level

Figure 3-20. Au/Ag versus depth in the Ropes deposit in ore characterized by dispersed pyrite with gold in quartz - sericite - chlorite rock (from data in table 3-6).



Ropes Mine Au / Ag vs Depth
2
1
0
Au/Ag
0
1000
2000
Depth (feet)

Figure 3-21. Au concentration versus depth in ore characterized by dispersed pyrite with gold in quartz - sericite - chlorite rock, Ropes deposit (from data in table 3-6).

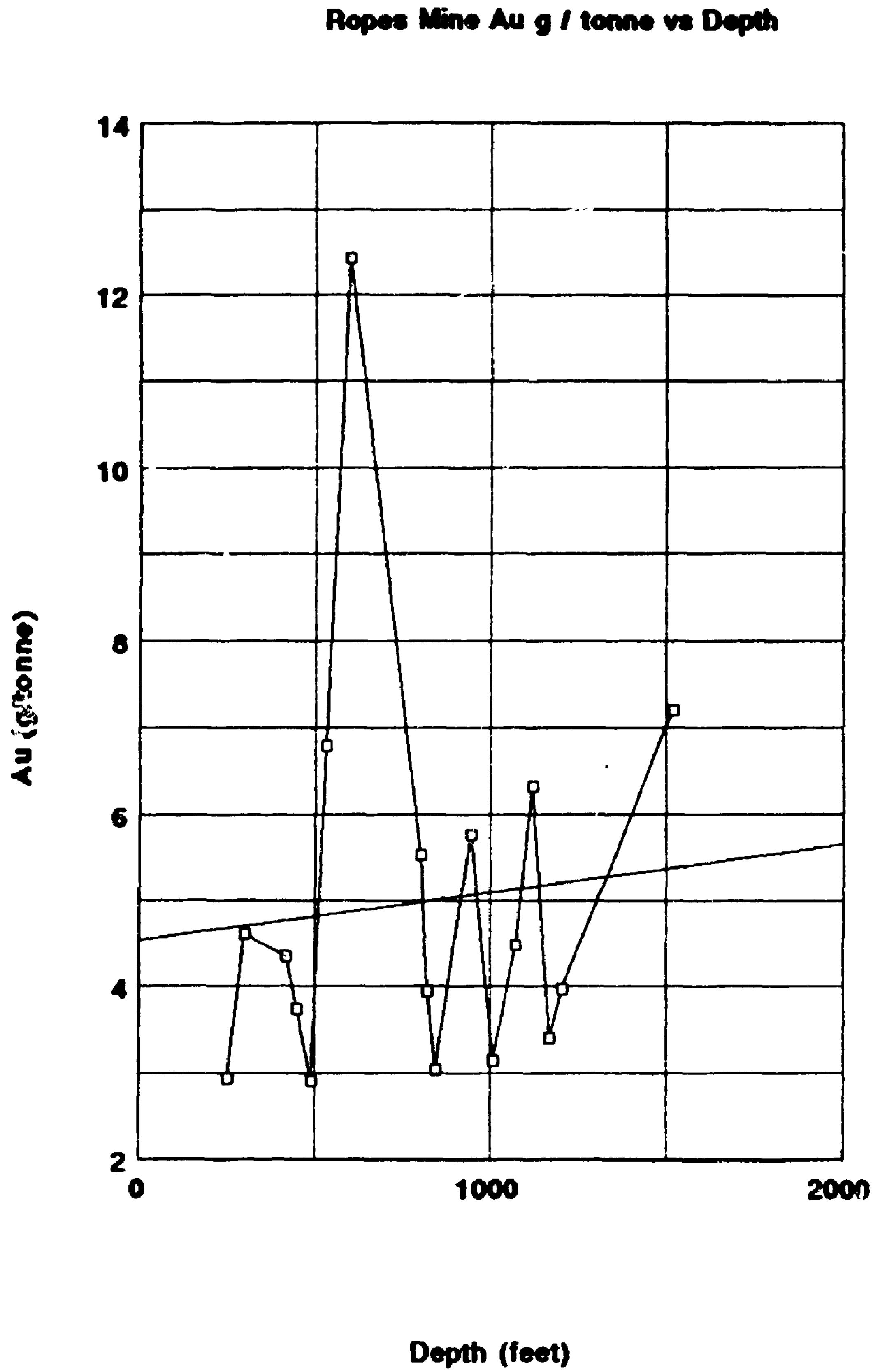
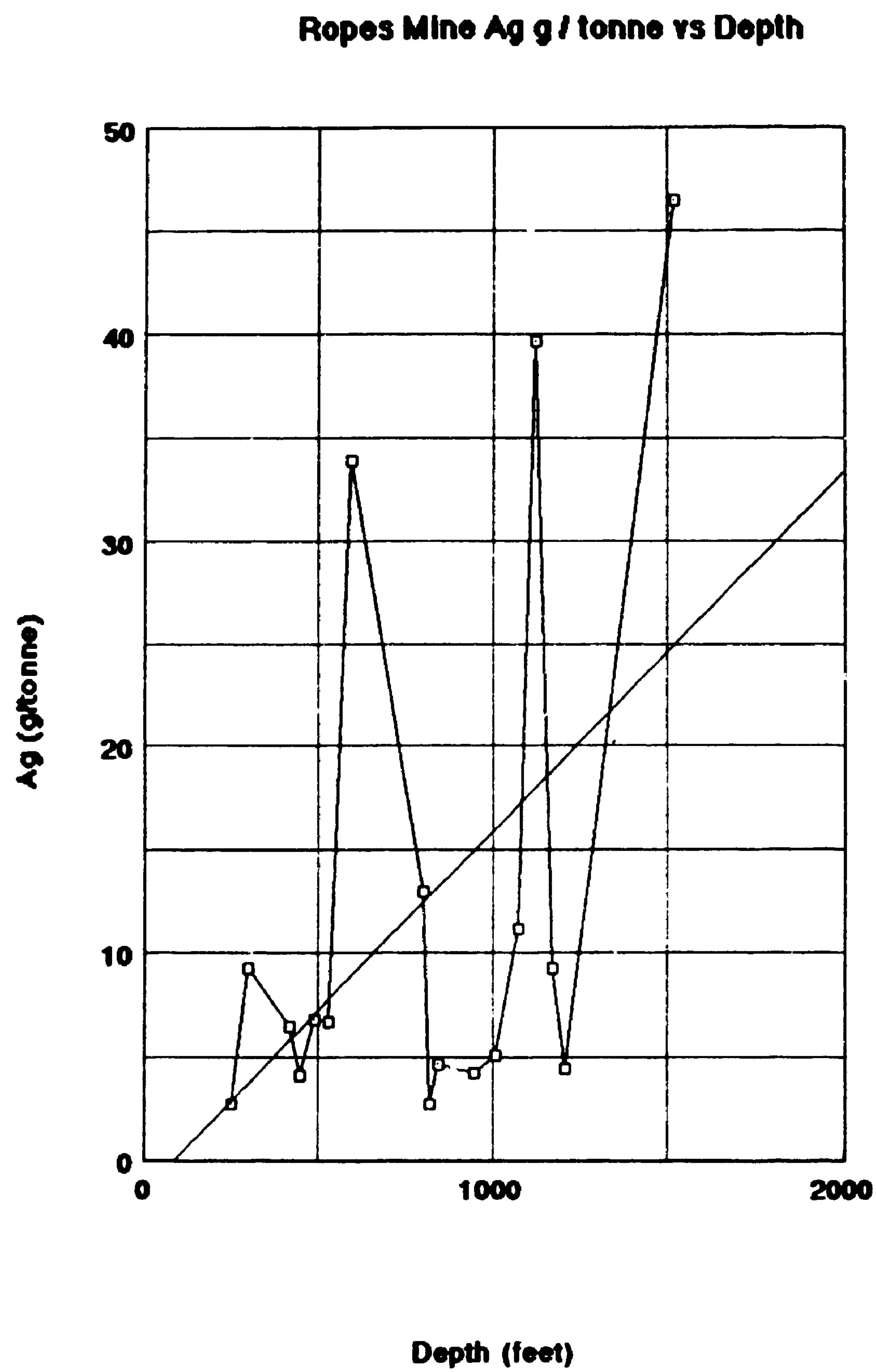

Ropes Mine Au g / tonne vs Depth
14
12
10
8
6
4
2
0
1000
2000
Au (g/tonne)
Depth (feet)

Figure 3-22. Ag concentration versus depth in ore characterized by dispersed pyrite with gold in quartz - sericite - chlorite rock, Ropes deposit (from data in table 3-6).


Ropes Mine Ag g / tonne vs Depth
Ag (g/tonne)
50
40
30
20
10
0
0
1000
2000
Depth (feet)

and Ag, interpreted by Bideaux (1982) as indicating, in part, different host minerals. Some correlation between Au and Ag is evident, however, for the sample set used in table 3-6, with greater Au concentrations generally accompanied by greater Ag concentrations (figure 3-23).

A spherical variogram constructed for the Ropes deposit (appendix A) (Bideaux, 1982) levels out at a variance of 1.45 (log e) units, the overall variance of the deposit (figure 3-24). This indicates that for any point in the deposit, knowledge of Au concentration further than 27.4 m away is of no value in predicting Au concentration at that point. This distance is considered unusually large for a gold deposit (Bideaux, 1982), and is interpreted to reflect rather uniform distribution of dispersed pyrite with gold. The intercept with the Y axis is approximately 0.3 variance (log e) units and is the nugget effect. The value is considered low for a gold deposit, and values twice as large are not uncommon (ibid.). The positive value for the nugget effect indicates the degree to which reassay of the same sample will differ, possibly due to assay errors, sample preparation, or random inclusion of a flake of gold in one or the other splits of the same sample.

Figure 3-23. Au concentration versus Ag concentration in ore characterized by dispersed pyrite in quartz - sericite - chlorite rock, Ropes deposit (from data in table 3-6).

Ropes Mine Au vs Ag

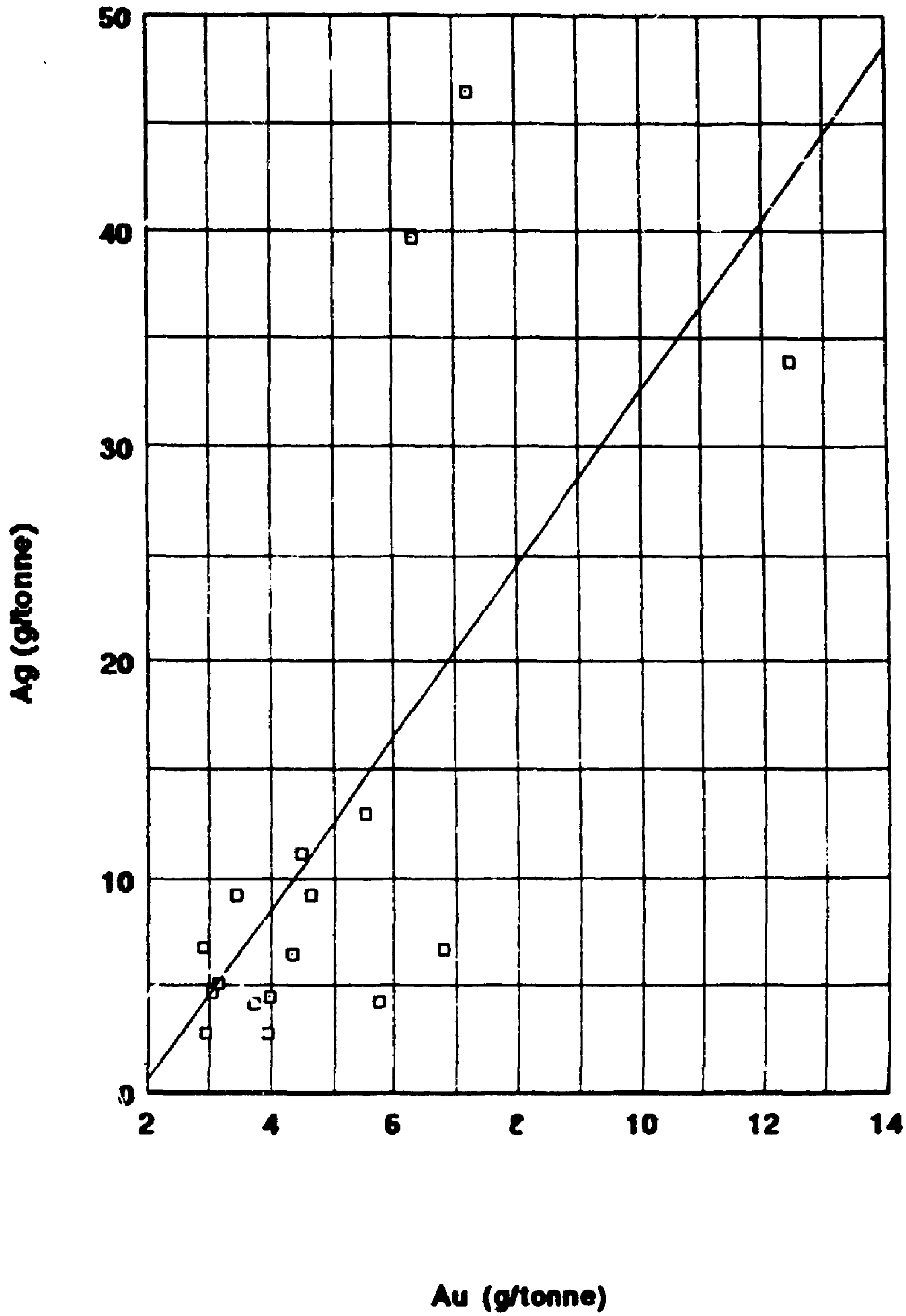
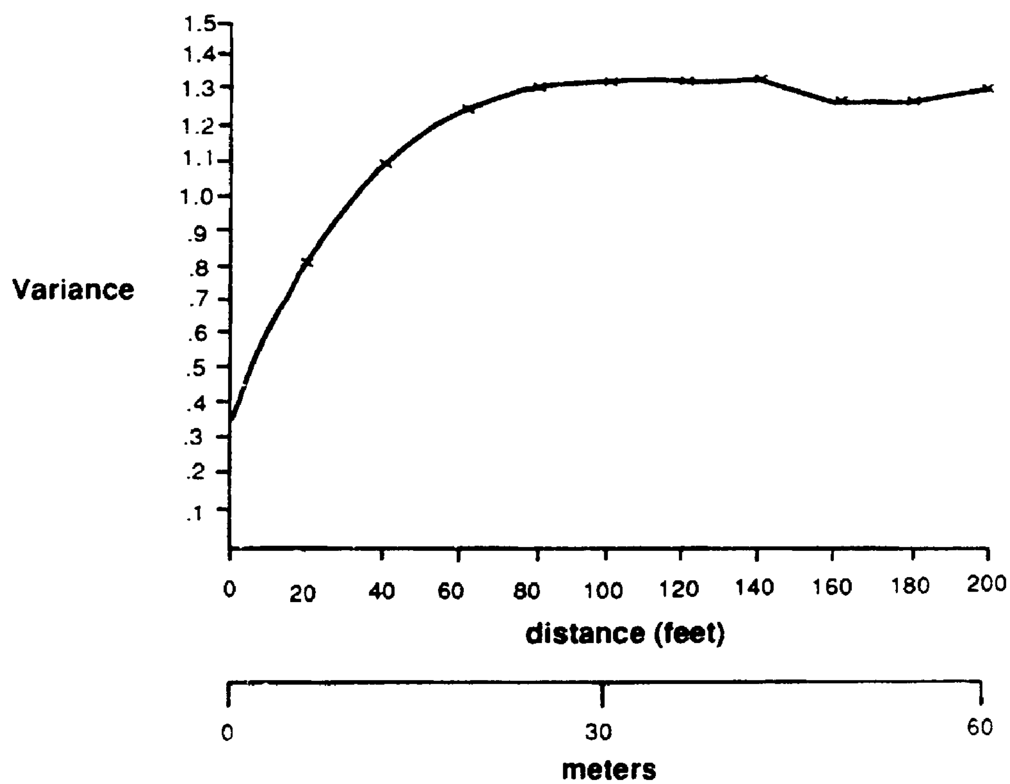


Figure 3-24. Average spherical variogram for gold, Ropes deposit (after Bideaux, 1982).


Variance
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
20
40
60
80
100
120
140
160
180
200
distance (feet)
0
30
60
meters

3.5.2 Auriferous Quartz Veins

3.5.2.1 Distribution, Geometry and Gold Concentration of Auriferous Quartz Veins

Auriferous quartz veins are concentrated at the south side of the deposit. Individual veins average 20 cm thick (plate 3-12b c) and are perhaps 12 m in horizontal and 15 m in vertical extent, but collectively these veins are grouped en echelon and locally form ore shoots 8 to 11 m thick with the quartz veins separated by auriferous foliated quartz - sericite - chlorite rock. Veins strike in right stepping en echelon fashion at 065° across the 080° trend of the quartz - sericite - chlorite rock, dip vertically to 85° south, and are in a slight sigmoidal geometry (figure 3-25). They are progressively further east in successively deeper mine levels (figure 3-18). Eight major shoots made up of these veins were mined in the 1800's and 1890's above the 800 level. Broderick (1945) implied that single large quartz veins ranged up to 11 m thick, 60 m in horizontal extent, and 76 mm vertical extent, but examination of the old mine working concurrent with development of the modern Ropes mine, and detailed historic descriptions (Ropes Gold and Silver Mining

Company,1884-1894) indicate the old stopes were ore shoots made up of series of smaller individual quartz veins and intervening auriferous foliated quartz - sericite - chlorite rock.

Overall, metal concentrations in the veins average 46 g/tonne Au and 323 g/tonne Ag (table 3-7). One example of a vein, the Lower Secondary Drift vein east of the 1620 level is 30 m in strike extent, 1 m thick, and averages 25 g/tonne Au from 5 assays across the vein ranging from 12.7 g/tonne to 49.1 g/tonne (figure 3-25). Abundances of Ag were not determined for this vein.

The quartz veins have greater concentrations of Au than most of the ore characterized by dispersed pyrite with gold in quartz - sericite - chlorite rock. Zones of greater than 4 g/tonne Au concentration in the quartz - sericite - chlorite rock are not symmetrically zoned about the veins, rather, these are more centrally within the quartz - sericite - chlorite rock north of the veins. In some instances, concentrations of greater than 4 g/tonne Au with dispersed pyrite in quartz - sericite - chlorite rock are along the eastward continuation of the same 065° trend from the

Figure 3-25. Geologic plan of the 1620 level, Ropes deposit, with distribution of zones of greater gold concentration in ore characterized by dispersed pyrite, at west end of diagram, and auriferous Lower Secondary drift quartz vein at east end of diagram. Note low angle sigmoidal shape of vein.

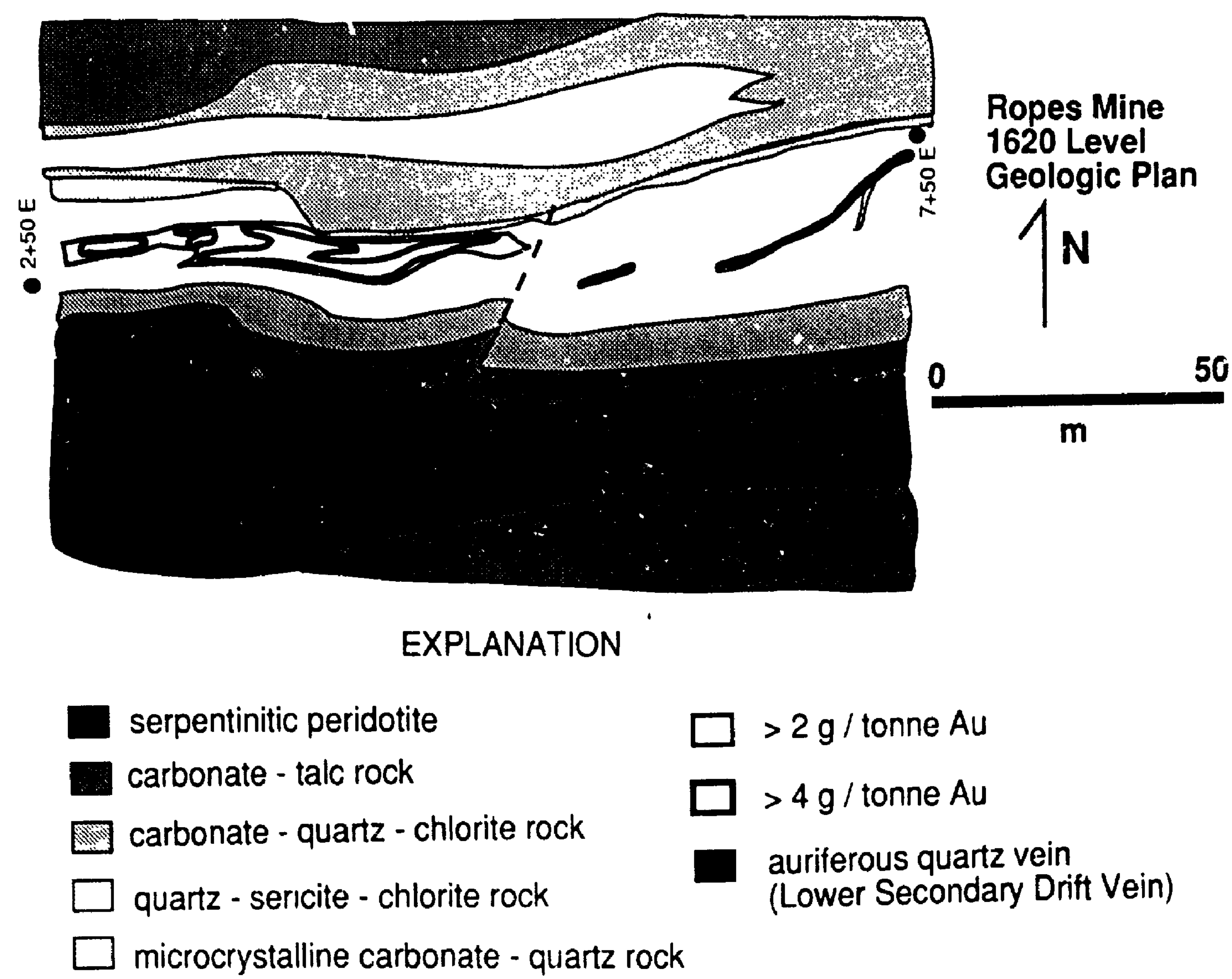

Ropes Mine
1620 Level
Geologic Plan
N
0
50
m
2+50 E
7+50 E
EXPLANATION
serpentinitic peridotite
carbonate - talc rock
carbonate - quartz - chlorite rock
quartz - sericite - chlorite rock
microcrystalline carbonate - quartz rock
> 2 g / tonne Au
> 4 g / tonne Au
auriferous quartz vein
(Lower Secondary Drift Vein)

Table 3-7: Au/Ag for auriferous quartz veins with tetrahedrite from tne Ropes deposit

Depth below surface (m)		core inter-val (cm)	Au(g/ (tonne)	Ag(g/ tonne	Au/Ag
1.	153	37	24.59	120.55	.20
2.	244	34	20.31	527.74	.04
3.	244	46	74.66	608.90	.12
4.	274	30	39.83	22.60	1.76
5.	326	61	27.91	230.48	.12
6.	341	67	79.04	69.52	1.14
7.	341	122	50.17	393.15	.13
8.	462	138	49.01	611.64	.08
arithmetic average:			46	323	0.45

Sample locations:

Drill Hole No.		Vein interval in core meters
1.	RU-118	29.26- 29.63
2.	RU-115	4.66- 5.00
3.	RU-117	4.11- 4.57
4.	RS-19	301.75-302.05
5.	RU-127	26.58- 27.19
6.	RS-17	392.58-393.25
7.	RU-134	148.44-149.66
8.	RU-126	240.94-242.32

east end of old stopes which marked concentrations of quartz veins (figures 3-26, 3-27).

3.5.2.2 Minerals and Textures of Auriferous Quartz Veins

Quartz veins are saccharoidal white to light gray quartz, with pyrite and minor argentiferous tetrahedrite, galena, and chalcopyrite; and rare gold, molybdenite, dyscrasite, tourmaline, and native silver. They are generally layered, with foliated septa of quartz - sericite - chlorite rock common toward the vein margins (plate 3-12b, c). Quartz has undulatory extinction, subgrain development, and mortar texture along grain boundaries (plate 3-12d).

3.5.2.3 Gold/Silver of Auriferous Quartz Veins

Quartz - tetrahedrite veins considered in this study average 46 g/tonne Au, ranging from 20.3 to 74.7 g/tonne. Ag content averages 323 g/tonne, ranging from 22.60 to 611.64 g/tonne. Au/Ag varies widely from 0.08 to 1.76, averaging 0.45 (table 3-7).

Figure 3-26. Geologic plan of the 530 and 800 levels, Ropes deposit, illustrating distribution of zones of greater gold concentration in ore characterized by dispersed pyrite, in relation to stopes developed on auriferous quartz veins in the late 1800's. Note distribution of zone of greater gold concentration eastward from east end of old stope on 800 level. Rock types other than quartz - sericite - chlorite rock are unpatterned.

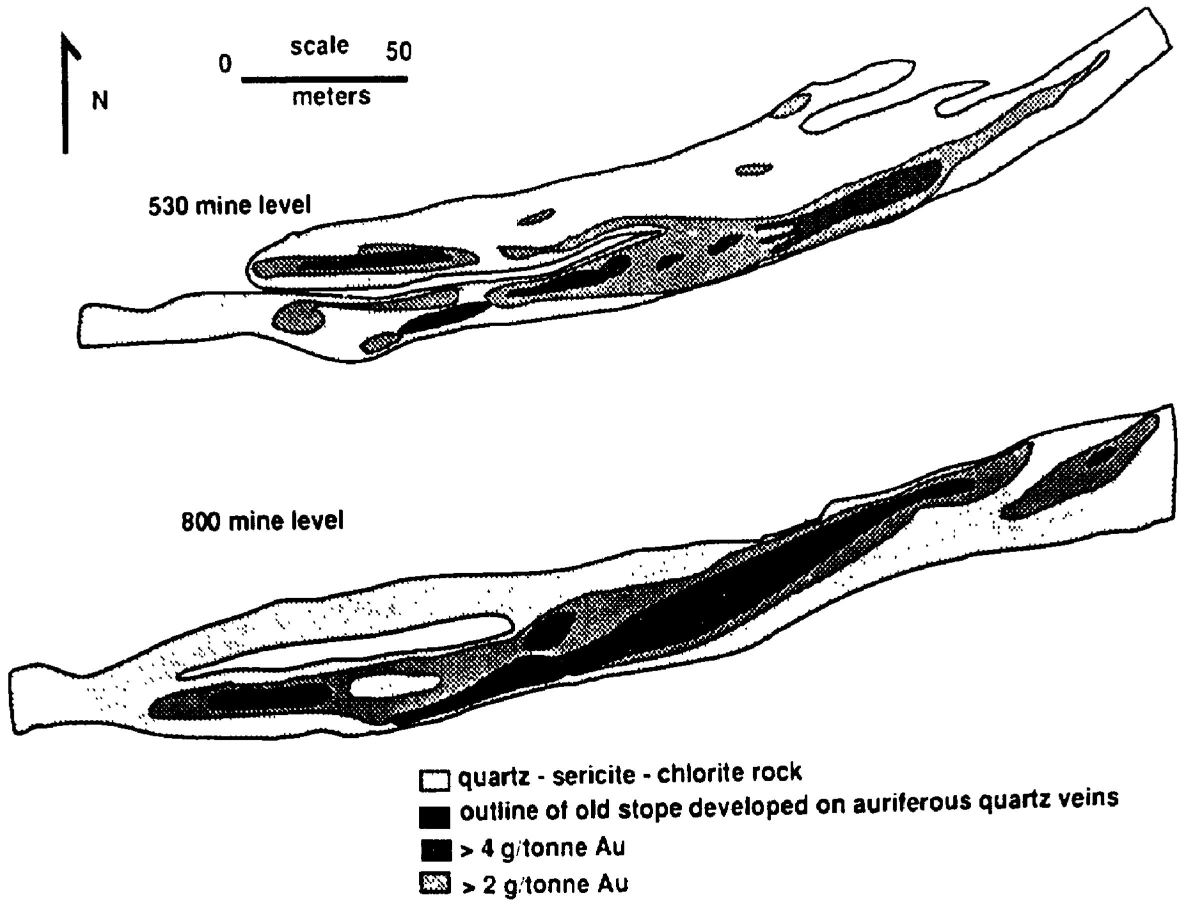
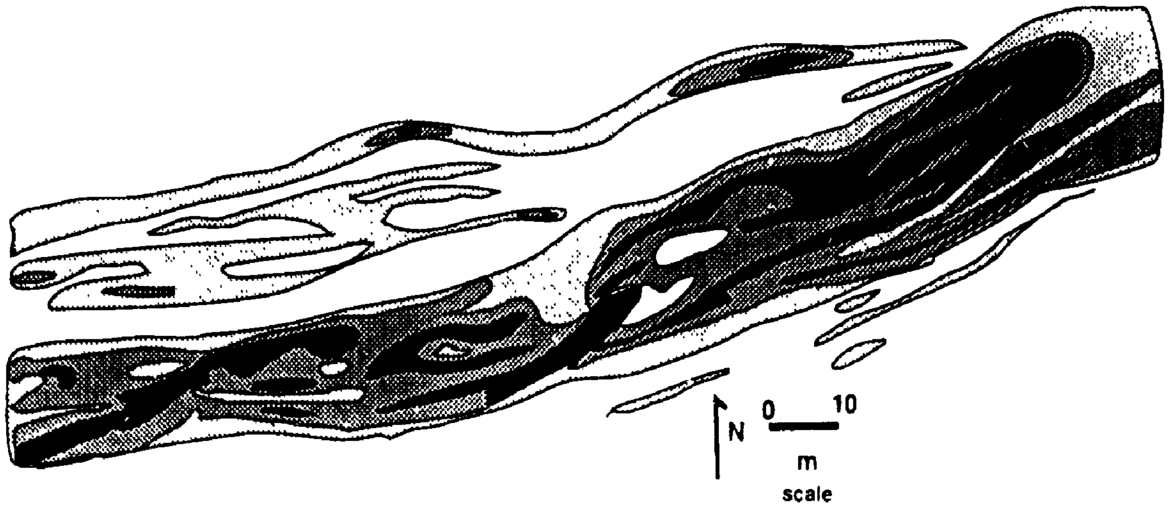

N
0 scale 50
meters
530 mine level
800 mine level
quartz - sericite - chlorite rock
outline of old stope developed on auriferous quartz veins
> 4 g/tonne Au
> 2 g/tonne Au

Figure 3-27. Contoured level plan of gold assays for part of the 650 level, Ropes deposit, with distribution of zones of greater gold concentration with dispersed pyrite in the quartz - sericite - chlorite rock, in relation to stopes developed on quartz veins in the late 1800's. Note en echelon distribution of old stopes developed on auriferous quartz veins.



650 LEVEL Contoured Gold Concentration Plan Map

- Outline of old stope developed on auriferous quartz veins
- > 4 g/tonne Au
- > 2 g/tonne Au
- > 0.7 g/tonne Au

3.6 Non - Auriferous Veins

Milky white, vitreous, medium to coarse grained quartz veins commonly cut the east northeast foliation in the quartz - sericite - chlorite rock at a high angle. Some dip steeply, whereas others are shallowly dipping. The veins are not auriferous and are commonly up to 10 cm thick and several meters in length. They are approximately 1% of the quartz - sericite - chlorite rock. Quartz in the veins has full extinction under crossed polars, simple grain boundaries, and locally has minor pyrite.

Banded dolomite veins commonly strike 015° and dip nearly vertically. They cut the auriferous quartz veins. Massive, planar sided, coarse crystalline white dolomite veins up to 10 cm thick cut all other veins and are undeformed. There are flat lying extensional dolomite veins in carbonate - talc rock (plate 3-18c), and also shallowly dipping carbonate veins offset in stepwise fashion along foliation parallel structures (plate 3-18d).

3.7 Structure

Structural elements defined by the planar orientation of alteration minerals spatially associated with gold, by auriferous quartz veins, or by contoured maps of gold concentration, are used to interpret style and sense of relative movement in the deposit, which is correlated with greenstone belt and regional structures. Inferences are made about the tectonic regime during formation of the Ropes deposit. Terminology is: S = schistosity (schistosite), C = shear plane (ciscaillement), C' = shear band, or extension crenulation cleavage, T = tension fracture, $\tilde{o}_1$ = maximum principal stress, D = principal displacement shear parallel to C, and P = thrust shear (Skempton, 1966; Tchalenko, 1970; Lister and Snokes, 1984; Roberts, 1987; and Groshong, 1988).

The tabular, near vertical trend of quartz - sericite - chlorite rock which hosts the deposit is bound north and south first by generally well foliated carbonate - quartz - chlorite rock, next by carbonate - talc rock, and then outward by unfoliated serpentinitic peridotite.

3.7.1 Foliation

An 065° vertical to steep north foliation in the deposit is defined mainly by planar alignment of talc in the carbonate - talc rock, chlorite in carbonate - quartz - chlorite rock, and sericite and chlorite in the quartz - sericite - chlorite rock. This is interpreted as tectonic schistosity, or S fabric, because it is a planar orientation of secondary minerals which cut and locally displace relict primary magmatic features such as domains of former feldspar phenocrysts. Sericite rich former feldspar domains are locally elongate parallel to the foliation, have blurred rather than sharp outlines, and a flat rather than rectangular morphology (plates 3-1d, 3-2a, b, c).

Auriferous fine grained pyrite, with and without symmetric quartz pressure fringes, is locally concentrated along the 065° foliation and therefore, development of foliation was concurrent with deposition of auriferous pyrite. Coarse grained barren pyrite is commonly more extended parallel to foliation (plate 3-5a), and therefore formed earlier than the fine grained pyrite. Compositional layers in the carbonate - quartz - chlorite rock, defined by alternating carbonate - quartz rich laminae and chlorite rich laminae, form the foliation (plate 3-8a).

Widespread preservation of rectangular shaped former feldspar domains in quartz - sericite - chlorite rock, pseudomorphd by sericite (plate 3-1c), and of former olivine domains in the serpentinitic peridotite, pseudomorphed by serpentine (plate 3-10a), indicate that not all rock in the deposit was pervasively deformed; rather deformation was concentrated along discrete zones (plate 3-2c). This is consistent with micro to macro lithons of relatively undeformed rock, separated by well foliated rock, observed in many brittle - ductile shear zones (Hodgson, 1989). Parts of the carbonate - quartz - chlorite rock and carbonate - talc rock are massive and isotropic (plate 3-11a, b). It is uncertain whether these more massive parts, which lack relict igneous textures, have not been sheared, or whether they have been annealed and recrystallized after pe strain, resulting in the observed isotropic texture.

Well foliated carbonate - quartz - chlorite rock and carbonate - talc rock which bound the trend of quartz - sericite - chlorite rock do not have any primary magmatic textures, but do have local S and S -

C tectonic fabrics (plate 3-6c). The intervening quartz - sericite - chlorite rock was apparently a more competent block. In zones of intense fabric development, an S - C fabric with sigmoidal microshear planes (S) is between macroscopic shear planes (plate 3-8c). A slight, locally present subvertical second foliation strikes 330° and is coarser grained sericite and chlorite laths. Crenulation is confined to minor zones where platy minerals are deformed into microbuckles, and their hinges generate a subhorizontal lineation in the plane of the schistosity (plate 3-8d).

In the Ropes deposit contacts between the quartz - sericite - chlorite rock, formerly dacite, and rocks derived from a peridotite protolith defined pre - existing planes of weakness. Unlike faults or shear zones with orientations directly related to a principal stress by fracture criterion (Anderson, 1951), the orientation of reactivated zones of weakness such as contacts between rock types are not strictly governed by the exact orientation of the stress that causes the movement (Lisle, 1989). Therefore, this setting is not comparable to classic shear zones developed in initially homogeneous isotropic media (Ramsey and Huber, 1983). High strain rates can develop where deviations from a simple regional pattern are created by variations in rock type, therefore variable initial orientation of contacts is important in localizing shear zones (W. F. Cambray, Michigan State University, 1989, personal communication). The low angle sigmoidal orientation of the S fabric in the quartz - sericite - chlorite rock is identical to fabric developed experimentally in clay rich rock between two fault planes (Petit, 1987). In the case of the Ropes deposit it indicates a competency contrast between the serpentinitic peridotite and associated rocks, and the quartz - sericite - chlorite rock.

3.7.2 Ore Related Structures

The Ropes main ore zone trends 080° overall, but is internally comprised of 070° to 065° trending zones of greater Au concentration, which host most of the gold (map plate 5). These take two forms: the first is right stepping en echelon low angle sigmoidal zones of greater than 4 g/tonne Au concentration within ore characterized by dispersed pyrite (figure 3-19), and the second is auriferous quartz - tetrahedrite veins with similar geometry and orientation (figure 3-25).

3.7.2.1 En Echelon Zones of Gold Concentration

Zones with greater than 4 g/tonne gold concentration, defined by assay data, are most centrally within the Ropes main ore zone. The middle parts of these higher grade zones strike in right stepping en echelon fashion across the overall 080° trend of the ore body at approximately 065° whereas their extremities nearer the contacts with the carbonate - quartz - chlorite rock strike approximately 070°, forming a low angle sigmoidal pattern across the zone, which is most prominent on the east end of the 1152 level (figure 3-19). This geometry is consistent with greater movement being accomodated at the margin of more ductile carbonate - quartz - chlorite rock, where schistosity was flattened to the local 080° plane of shear, represented by the contacts between contrasting rock types within the deposit. This overall 080° part of the trend of quartz - sericite - chlorite rock which hosts ore is a local perturbation in the 070° overall strike of the trend of quartz - sericite - chlorite rock (figure 3-28), which acted as a dilational bend, or releasing bend, (Sibson, 1985) during dextral shear along the overall 070° trend (figure 3-29).

Figure 3-28. Vertical long section of total ore thickness in relation to strike of the north contact of the trend of quartz - sericite - chlorite rock for upper part of the Ropes main ore zone. Note that position of main ore zone correlates with broad area between 20 m and 30 m contours on north contact, which indicates nearly constant 080° strike of the trend of quartz - sericite - chlorite rock in the part where ore is localized.

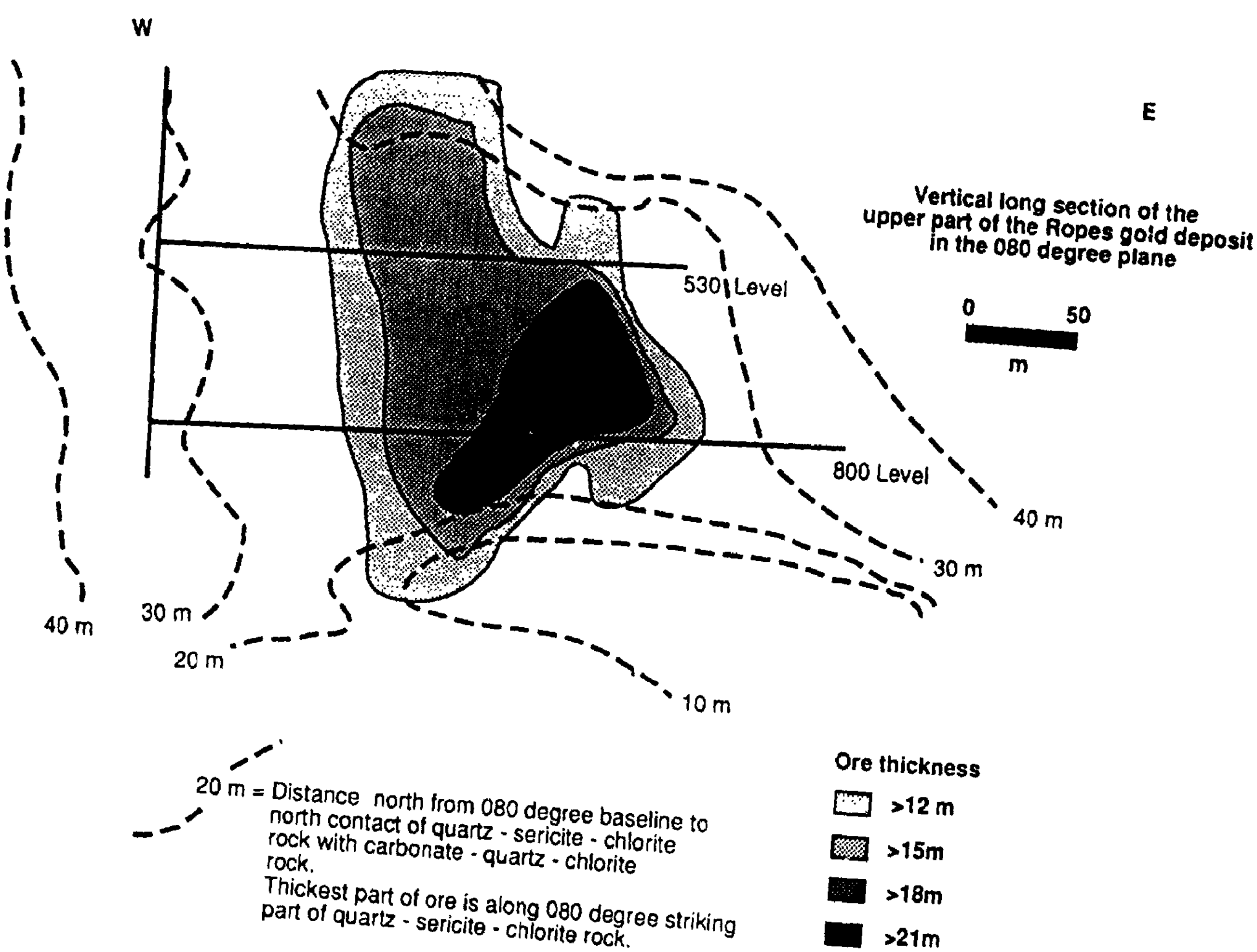
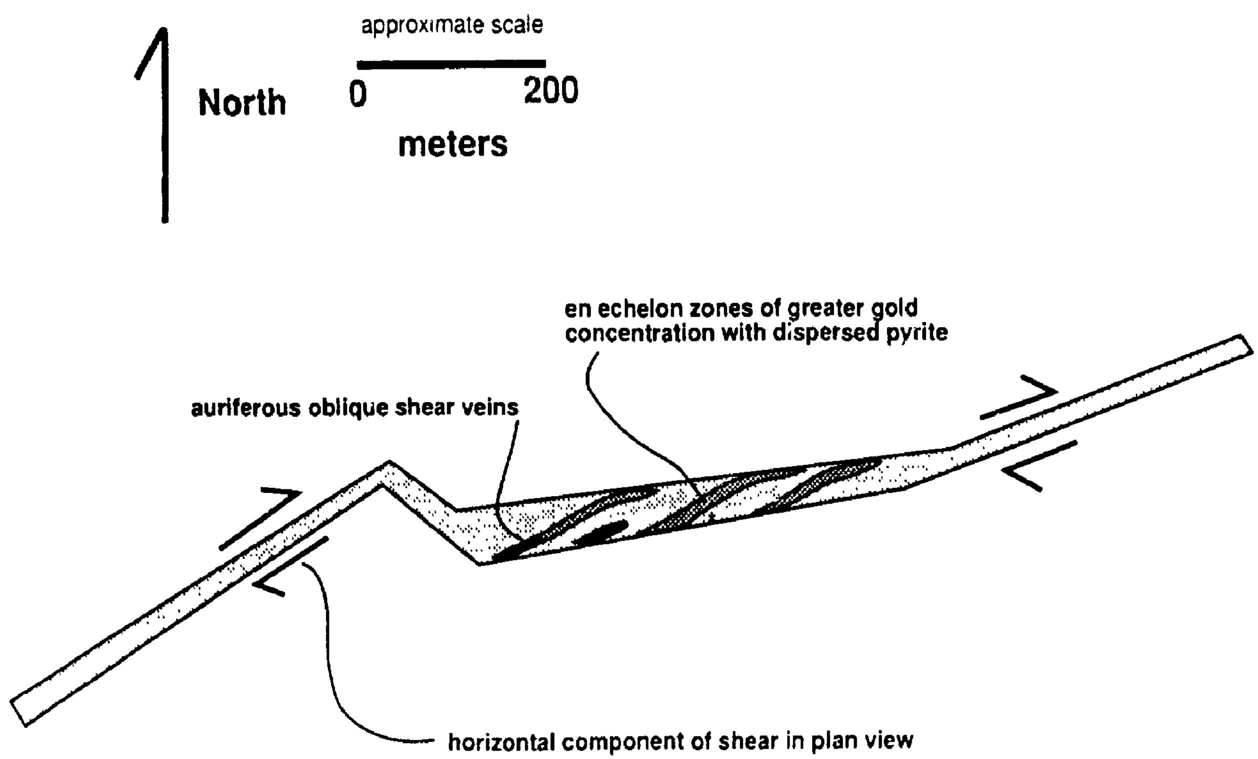

W
E
Vertical long section of the upper part of the Ropes gold deposit in the 080 degree plane
0
50
m
530 Level
800 Level
40 m
30 m
20 m
10 m
40 m
30 m
20 m = Distance north from 080 degree baseline to north contact of quartz - sericite - chlorite rock with carbonate - quartz - chlorite rock.
Thickest part of ore is along 080 degree striking part of quartz - sericite - chlorite rock.
Ore thickness
>12 m
>15m
>18m
>21m

Figure 3-29. Plan view of dilational bend model for Ropes deposit, illustrating right stepping orientation of both en echelon zones of greater gold concentration with dispersed pyrite, and auriferous oblique shear veins relative to dilational bend in shear zone.


North
approximate scale
0
200
meters
en echelon zones of greater gold concentration with dispersed pyrite
auriferous oblique shear veins
horizontal component of shear in plan view

The sigmoidal zones of Au concentration with dispersed pyrite, as well as the auriferous quartz veins, are interpreted to indicate local extension within a dilational bend, with a component of positive volume change in the shear zone, in an otherwise compressive tectonic regime (Ramsay and Huber, 1983). Increased pore pressure within the shear zone as microfractures filled with fluid, combined with the local extensional effect of the dilational bend (figure 3-29), may have contributed to local extension (Morris, 1988). Slip transfer in a dilational bend involves extension localized in the bend, or step over. Formation of dilational bends involves local loss of cohesion, or brittle failure, in an otherwise ductile environment (Guha and others, 1983).

3.7.2.2 Auriferous Quartz Veins

Vertically dipping, steeply westward plunging auriferous quartz - tetrahedrite veins occur progressively further east in successively deeper levels of the mine (figure 3-18). Their eastern limits on successive levels define an overall 55° plunge to the east northeast. These layered, auriferous, tetrahedrite bearing quartz veins with aligned schistose inclusions of sericite - quartz -

chlorite wall rock are near the south side of the main ore zone and have an orientation the same as the zones of schistosity parallel gold concentration with dispersed pyrite, which are more centrally within the trend of quartz - sericite - chlorite rock (figures 3-26, 3-27). The veins are oriented nearly parallel to the schistosity. They contain schistose septa identical in composition to the quartz - sericite - chlorite wall rock (plate 3-12b, c) and have quartz with undulose extinction and subgrain development textures (plate 3-12d) indicating grain size reduction. These characteristics are more compatible with an origin as oblique shear veins (Hodgson, 1989), formed in the direction of shear movement by overriding of asperities (Roberts, 1987) than with an origin as en echelon extension veins which would initially be oriented parallel to the maximum principal stress (Ramsay and Huber, 1983). Oblique shear veins are inclined to shear zone margins in the same way as P shears, and show the same sense of en echelon stepping as the sense of movement across the zone containing them (Hodgson, 1989). In the case of the Ropes deposit, this is a dextral sense in plan view (figure 3-29). An origin for the quartz - tetrahedrite veins, and the en echelon zones of Au concentration with dispersed pyrite, as tension shears (Groshong, 1988), extension veins, or Riedel shears

(Tchalenko 1970) in a sinistral shear zone is not indicated because the orientation of the tips of the veins with respect to the shear zone margin, and the orientation of the ends of the en echelon zones of Au concentration, is not consistent with the sense of rotation expected in sinistral shear. Furthermore, veins in extension fractures are not generally layered with schistose inclusions (Roberts, 1987).

3.7.3 Low Angle Reverse Fault

The Ropes deposit and adjacent serpentinitic peridotite is cut by an 060° striking, 20° south dipping reverse fault at the 900 level (map plate 4). Maximum northward displacement of the upper block is 15 m at the east end of the deposit and less toward the west end of the deposit. Hence, movement on the fault was scissors - like, with clockwise rotation of the lower block relative to the upper block. The fault surface ranges from a sharp plane, up to a meter of talcose gouge. Minor faults with the same orientation are marked by terminated dolomite, pyrite, chalcopyrite, and, in the serpentinitic peridotite, by sprays of millerite.

Offset of rock types within the deposit across the fault zone is generally greater at the south side than at the north side, and the orebody thins down dip toward the fault zone, but thickens below it, indicating that at least some movement on the fault may have occurred synchronously with gold concentration and attendant alteration, and that the low angle reverse fault may have exerted some control on the distribution of ore.

Some limited movement was inferred by previous workers (Resource Exploration, 1980a, b) on a postulated low angle fault above the 420 level, however, most of the change in rock type at that location is the result of interfingering between quartz - sericite - chlorite rock on the 420 level with carbonate - quartz - chlorite rock above the 420 level (map plate 4).

3.7.4 Interpretation of Structure

The low angle sigmoidal geometry of both the quartz - tetrahedrite veins and the en echelon zones of greater Au concentration with dispersed pyrite are consistent with increased shear strain at both margins of a more competent block. In plan view, zones of gold concentration with dispersed pyrite in the main ore zone follow an 080° trend at shallow levels of the mine, but are increasingly along 065° trending en echelon zones at greater depths (map plate 5). This change to low angle en echelon zones may indicate control on localization of gold concentrations by more ductile features with increasing depth in the deposit. In the Ross mine in the Abitibi greenstone belt, for instance, Au concentrations are controlled by brittle shears near surface but by more ductile features with depth, and this is interpreted as reflecting the brittle - ductile transition (Troop and Spry, 1988).

The foliation and oblique shear veins in the Ropes deposit have a consistent orientation and may not have been rotated significantly after they were formed, suggesting that the veins formed late in the sequence of shear. Sigmoidal zones of gold concentration with dispersed pyrite in the quartz - sericite - chlorite rock, and oblique shear veins, have orientations nearly parallel to the S fabric, consistent with an origin as P shears. P shears commonly form at approximately 10° to the shear zone boundaries, after peak deformation, when resistance to shear is decreased by the presence of well developed planar fabric (Tchalenko, 1970).

Movement direction is commonly considered to be in the line perpendicular to the intersection of the shear zone margin with the plane of the oblique S fabric, and the sense of movement is inferred from the sense of obliquity of the fabric to the shear zone margin: in a ductile environment the acute angle between the S fabric and the shear plane faces away from the direction of movement. The sigmoidal zones of greater gold concentration with dispersed pyrite follow a 065° striking S fabric, interpreted as a mainly ductile feature. Contacts with nonfoliated serpentinitic peridotite north and south of the Ropes deposit strike 080° and are considered the major shear planes parallel to the C direction. Orientation of the S fabric relative to the C direction indicates a dextral component of movement when viewed in the horizontal plane, with the south side of the zone moving west southwest and the north side moving east northeast (figure 3-29). The trend of quartz - sericite - chlorite rock strikes 070° overall but 080° where it hosts the main ore zone. This 080° part of the trend acted as a dilational bend, or releasing bend (Gillerman, 1988: Sibson, 1985) during the indicated dextral movement. Releasing bends are commonly sites for ore deposits, even if the main fault trend is barren (Sibson, 1987), as in the case of the Illinois Creek polymetallic gossan developed along a shear in the Kaiyuh Mountains in West Central Alaska (Gillerman, 1988).

Old stopes at the south side of the Ropes main ore zone originated from mining auriferous quartz veins and groups of these veins in the late 1800's. These stopes plunge steeply west, are in slight right stepping en echelon array, and are progressively further east at deeper levels of the mine. Similarly configured vein systems have been interpreted as kinematic ore shoots, generated with their long axes nearly perpendicular to slip at bends in shear zones (McKinstry, 1948). Successive shoots form as shear progresses, so the locus of formation of additional shoots will migrate in the direction of slip.

In the case of the Ropes deposit, this suggests that slip was along a line plunging approximately 60° east in the plane of the shear zone (figure 3-18). A mineral lineation which plunges at an average of 68° east in the plane of the schistosity also suggests that slip was along a line inclined steeply to the east. This mineral lineation is best seen in weathered surface exposures at Ropes.

Figure 3-30. Block diagram of geologic and structural relations in the Ropes deposit, illustrating oblique dextral shear inferred from orientation of structural fabrics and features in the Ropes deposit.

O = Outline of Ropes main ore zone

S = Foliation (Schistosity)

C = Shear plane

D = Principal displacement shear

R = Riedel shear

S/C = S/C intersection lineation

L = Mineral elongation lineation

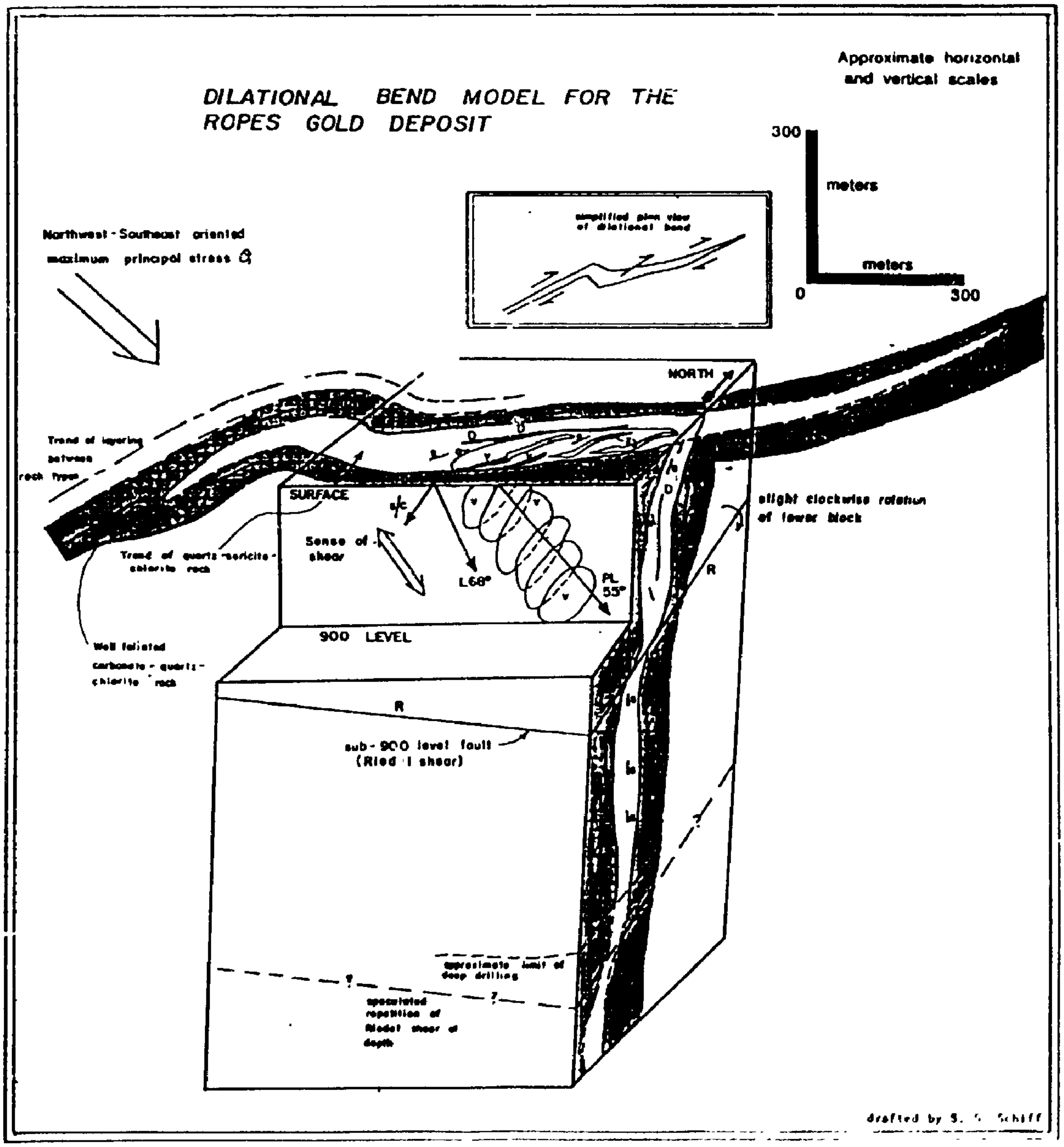
V = Auriferous oblique shear quartz veins

Z = En echelon zones of gold concentration with dispersed pyrite in quartz - sericite - chlorite rock.

√ = Sense of shear in plane of observation

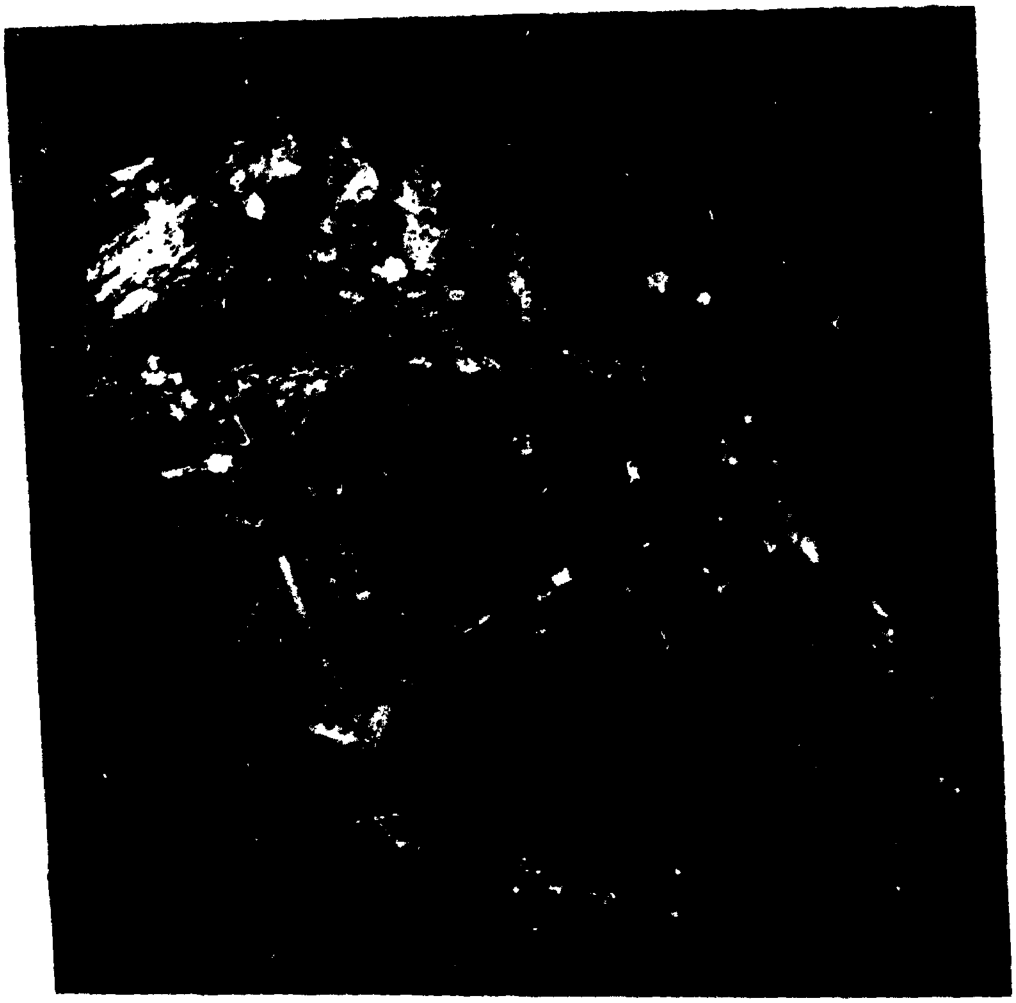
PL = Overall plunge of vein system defined by connecting the midpoints of old stopes developed on auriferous quartz veins

$\tilde{o}_1$ = Northwest - southeast oriented maximum principal stress inferred from simultaneous consideration of sense of shear or sense of offset on structures in the Ropes deposit and elsewhere in the Bjork - Lundeen block. (Refer to figure 3-31.)



DILATIONAL BEND MODEL FOR THE
ROPES GOLD DEPOSIT
Approximate horizontal and vertical scales
300
meters
meters
0
300
simplified plan view of dilational bend
Northwest - Southeast oriented maximum principal stress
NORTH
Trend of layering between rock types
SURFACE
s/c
Sense of shear
L68°
PL 55°
Trend of quartz-sericite-chlorite rock
slight clockwise rotation of lower block
R
900 LEVEL
Well foliated carbonate - quartz - chlorite rock
R
sub-900 level fault (Ried I shear)
approximate limit of deep drilling
speculated repetition of Riedel shear at depth
drafted by S. G. Schiff

Plate 3-19. Relations of structural fabrics in chloritic carbonate - talc rock from the Ropes deposit, at the scale of the hand specimen. Sample is 15 cm across. Sample mimics the deposit scale structural elements noted in figure 3-30 and is similarly oriented. Mineral lineation is noted by white arrow, lenses defined by S fabric are outlined in black on top right face, and S/C intersection lineation is marked by black lines on front of sample.



Elongation lineations are commonly difficult to observe in very fine grained rocks (Poulsen and Robert, 1989).

The trend of quartz - sericite - chlorite rock which hosts the Ropes main ore zone narrows to the east of the deposit, as well as toward surface updip from the deposit, where it is near vertical at depth but dips 70° south at shallow levels (map plate 4), possibly causing barrier conditions for ascending hydrothermal fluids, resulting in a further control on localization of ore. Microcrystalline, isotropic textured carbonate - quartz rock forms a nearly continuous layer of up to a meter thick along the north side of the main ore zone, parallel to the local 080° vertically dipping contacts between rock types. It is considered a principal displacement, or D, shear (Roberts, 1987), developed parallel to the local shear zone boundaries.

C' fabric develops in a rock which previously acquired a strong planar foliation (Malavieille, 1987). It extends this planar foliation in the manner of a small normal fault relative to the foliation. S - C' fabric is best observed in well foliated carbonate - talc rock east and north of the Ropes deposit, immediately north of the trend of quartz - sericite - chlorite rock which hosts the deposit. Alternating millimeter scale dark green chlorite rich and light green talc rich laminae form an S fabric which is offset or extended by a C' fabric in a manner which indicates an oblique north side down relative sense of movement for that location. The major 060° striking, 20° south dipping reverse fault below the 900 level is also in an orientation compatible with that of a large C' structure, or more properly a Riedel shear (Roberts, 1987). Riedel shears form in a brittle or brittle - ductile environment (Riedel, 1929). This structure, which displaces the main ore zone and the major rock types in the Ropes deposit (map plate 4) may have formed in response to more brittle conditions caused by decreasing temperature or increased silicification late in shear zone development.

Shear deformation likely proceeded at temperatures of less than one third the melting temperature of the framework minerals (Groshong, 1988), because strain was concentrated along discrete zones, supported by the fact that much of the rock retains its primary texture, indicating heterogeneous shear. Deformation was most likely by grain scale rotation, fracture and pressure solution, and by transgranular mechanisms.

3.7.5 Exploration Targets

Known or inferred zones of carbonate - talc rich serpentinitic peridotite may possibly host zones of altered volcanic rock, and therefore are prospective for hosting concentrations of gold similar to the Ropes deposit. Evidence for these carbonate - talc rich trends is based on direct observation of drill core and outcrop, and is also inferred from the presence of linear trends of lower total magnetic field within the serpentinitic peridotite. Magnetite formed during serpentinization is commonly consumed during carbonate - talc alteration by a reaction such as $Fe_3O_4 + 3CO_2 = 3FeCO_3 + 1/2\ O_2$ (Groves and others, 1974; Groves and Keays, 1979). Rock types near the Ropes deposit can be mapped by their magnetic signature. Approximate values are: serpentinitic peridotite > 61,000 gammas, felted - textured serpentinite = 59,000 to 61,000 gammas, carbonate - talc rock = 57,500 to 61,000 gammas, basalt = approximately 57,000 gammas, and dacite tuff, locally altered to quartz - sericite - chlorite rock < 57,000 gammas (Norby, 1989).

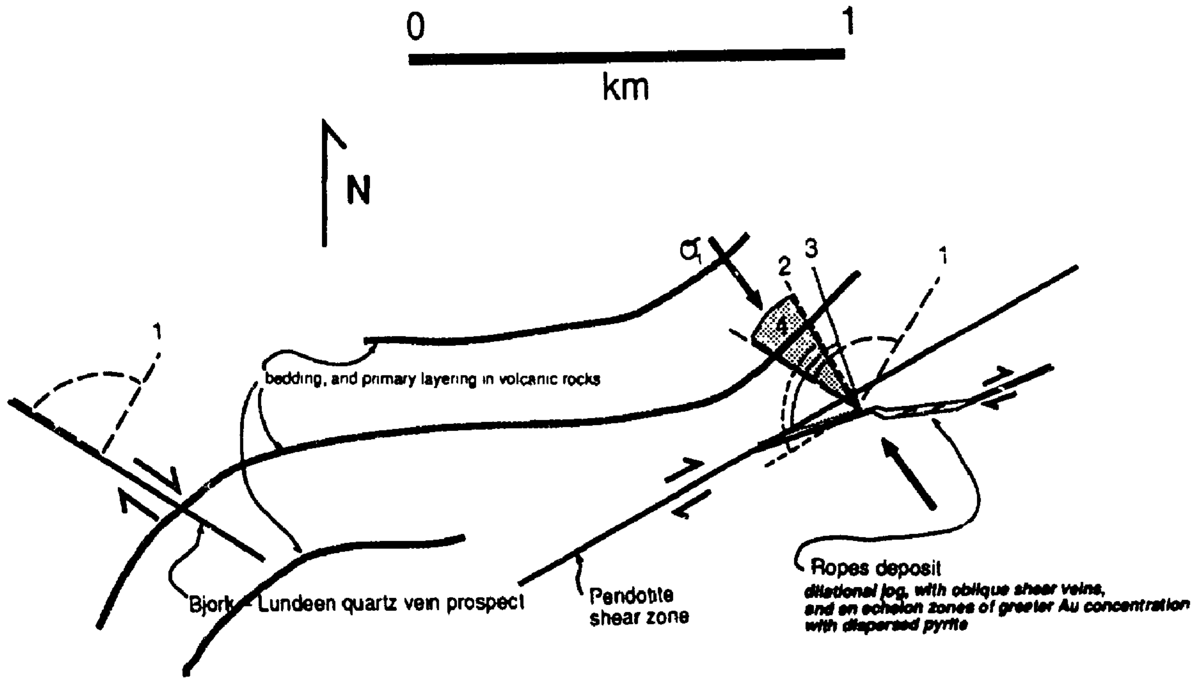
Untested exploration targets in the vicinity of the Ropes deposit include (map plate 2): 1.) A probable zone of carbonate - talc rock under the north arm of Deer Lake, north of the Ropes deposit and west of Deer Lake road. This is accompanied by a dextral fault offset of the margin of the Deer Lake Peridotite in the NW1/4 NE1/4 Section 29, T48N, R27W, 2.) An extension southwest from the main ore zone of a 058° trend of foliated carbonate - talc rock. The extension of this trend at 450 m southwest of the Ropes deposit is coincident with a 54,000 gamma magnetic low (Norby, 1989) which is consistent with the possibility of an inlier of felsic volcanic rocks at that location, 3.) The near surface possible east or northeast extension of the trend of quartz - sericite - chlorite rock which hosts the Ropes deposit east of the eastern Ropes property line and west of drill hole DLP - 1, 4.) The trend of felted textured serpentinite south of the Ropes deposit known as the south shear, 5.) The Middle trend of quartz - chlorite - sericite - chlorite rock, the shallow part of which has been adequately drill tested northwest and west of the Ropes deposit. North of the Ropes deposit, the trend pinches out in the shallow subsurface along strike to the east, and no further work is recommended in these previously drilled areas. However, thin intervals of gold concentration encountered in the shallow parts of the Middle trend may be in an analogous position to minor gold concentrations which occur updip and west of the Ropes main ore zone above the 300 level. A hole drilled north from the 1284 level at 300 east for 300 m is recommended to test for potentially auriferous quartz - sericite - chlorite rock downplunge to the east from the subcrop of Middle trend rocks, and 6.) In Sections 17 and 20, T48N, R27W, immediately north of the main mass of the Deer Lake Peridotite, there is a magnetic high of approximately 800 gammas in an area underlain by Lower Proterozoic sedimentary rocks. This magnetic anomaly is separated from the large magnetic anomaly coincident with the exposed DLP by a narrow intervening east trending magnetic low in the east central part of Section 20 (Case and Gair, 1965). This magnetic low may represent an analogous geologic setting to the Ropes deposit in Archean rocks buried beneath Lower Proterozoic rocks.

3.7.6 Block Scale Structure

Combining data on several planes, assumed to have slipped in response to the same stress conditions, it is possible to determine the approximate direction of δ_1 (Angelier, 1979). If the components of movement indicated by fabrics in the Ropes deposit, by dextral offset of minor veins at the Bjork - Lundeen shear zone west of Ropes, and by dextral offset of the margin of the peridotite were formed during the same shortening, compression can be constrained as northwest - southeast directed (figure 3-31).

A prominent set of lineaments on aerial photographs in the Bjork - Lundeen block and Deer Lake Peridotite averages 058°, which closely corresponds to the strike of auriferous quartz - tetrahedrite veins in the Ropes deposit. Shear zones trending 058° with an 85° southeast dip are preferentially along the margins of lenses of serpentinitic peridotite, and rarely within volcanic rocks of the Bjork - Lundeen block. A second prominent set of lineaments averages 107°, which correspond closely to the strike of auriferous quartz veins at the Bjork - Lundeen prospect. These two directions intersect to form a rhombohedral pattern. The acute angle bisectrix of these direction is 082° which closely corresponds to the overall strike of the Ropes main ore zone. In the Abitibi greenstone belt, at any one place, one set of fractures is commonly dilatant and mineralized and one set is closed, poorly defined, and barren

Figure 3-31. Plan view of inferred orientation of compression in the late Archean, based on a simultaneous consideration of the senses of displacement or senses of shear on structures in the the Ropes deposit and other structures in the southwest part of the Marquette greenstone belt.



Ranges of possible orientations of horizontal components of maximum principal stresses which could account for dextral components of strain at:

1. Bjork - Lundeen prospect
2. Peridotite shear zone
3. Ropes deposit
4. Possible range of horizontal component of maximum principal stress which could simultaneously satisfy requirements for sites 1, 2, and 3 above

(Roberts, 1987; Bruce Wilson, Queens University, personal communication, 1986). Within the Bjork - Lundeen block and Deer Lake Peridotite, this is the case for the Bjork - Lundeen prospect, where the 107° trend has Au concentrations in quartz veins, and the conjugate direction is not well defined, and, conversely for the Ropes deposit, where the 058° trend has gold concentrations and the conjugate trend is not apparent. It apparently is not necessary that the overall strike of a prospective structural trend or stratigraphic horizon be parallel to either the 058° or the 107° trends, but it appears likely that zones of greater gold concentration may preferentially follow these directions or their approximately 082° bisectrix, as in the case of the line of gold occurrences eastward from the Michigan mine in the southwest part of the Bjork - Lundeen block (map plate 2).

3.7.7 Greenstone Belt and Regional Structures

The 058° direction is an integral element of a more widespread pattern evident, from the deposit scale to the regional scale. The approximately 058°/107° lineament pattern is repeated at larger scales within the Marquette greenstone belt, for example the northeast trending Peridotite shear zone, also known as the I-18 structure, is along the northwest side of the Deer Lake Peridotite, and the Dead River and Carp River shear zones strike southeast (figure 2-4). At the regional scale, the segments of the Great Lakes tectonic zone, a major suture zone between Late Archean Superior Province rocks, which includes the Marquette greenstone belt, and the older Archean gneisses to the south (Sims and others, 1980) are oriented approximately 063° and 110° (figure 2-1). A dextral component of movement on structures in the Bjork - Lundeen block is consistent with Late Archean transpression which is also inferred to have caused dextral movement along major east trending faults in the Vermillion greenstone belt of Minnesota (Hudleston and Southwick, 1984; Schultz - Ela, 1986; Hudleston and others, 1988), as well as along the segment of the Great Lakes tectonic zone south of Marquette (Chapter 2.2.2). Superior province structural trends have been interpreted as products of northwest - southeast oriented compression and transpression resulting in deformation that occurred between 2.70 and 2.68 Ga in the southern Superior province (Card, 1987; Colvine and others, 1988).

CHAPTER 4 MINERAL ISOTOPIC COMPOSITIONS AND AGES FLUID INCLUSION CHARACTERISTICS

4.1 Stable Isotope Systematics of Carbonate Minerals

Both calcite and dolomite have less $\partial^{13}C$ within quartz - sericite - chlorite rock than within serpentinitic peridotite, with the greatest $\partial^{13}C$ in the intervening carbonate - quartz - chlorite and carbonate - talc rocks. The $\partial^{13}C_{dolomite}$ from the Ropes deposit, expressed in parts per mil relative to PDB, ranges from -2.5 to -3.7 (figure 4-1, table 4-1). $\partial^{13}C_{dolomite}$ is less, and has a more limited range within quartz - sericite - chlorite rock which hosts ore, - 3.4 to -3.7, than in the bounding serpentinitic peridotite, carbonate - talc rock, and carbonate - quartz - chlorite rock, where it is -2.8 to -2.5. It is greatest in the carbonate - talc rock, -2.5 to -2.7, and only slightly less, -2.6 to - 2.8, in the serpentinitic peridotite. $\partial^{13}C_{calcite}$ ranges from -2 to -4 for the Ropes deposit. $\partial^{13}C_{calcite}$ within quartz - sericite - chlorite rock is less, at -3.3 to -4.0, than within the bounding serpentinitic peridotite, carbonate - talc rock, and carbonate quartz - chlorite rock, where it is -2.5 to -2.8, and is

Figure 4-1. Oxygen and carbon isotopic abundances for calcite and dolomite from 10 samples along a north trending traverse across the 530 mine level. Oxygen isotopic values are reported in conventional notation where $\partial^{18}O$ = [$^{18}O/^{16}O$ standard] - 1 x 10^3 o/oo). $\partial^{18}O$ is referenced to SMOW and $\partial^{13}C$ is referenced to PDB. Note uniform C and O isotopic abundances within ore. Rock types noted across bottom of diagram are: P = serpentinitic peridotite, T = carbonate - talc rock, C = carbonate - quartz - chlorite rock, Q = quartz - sericite - chlorite rock.

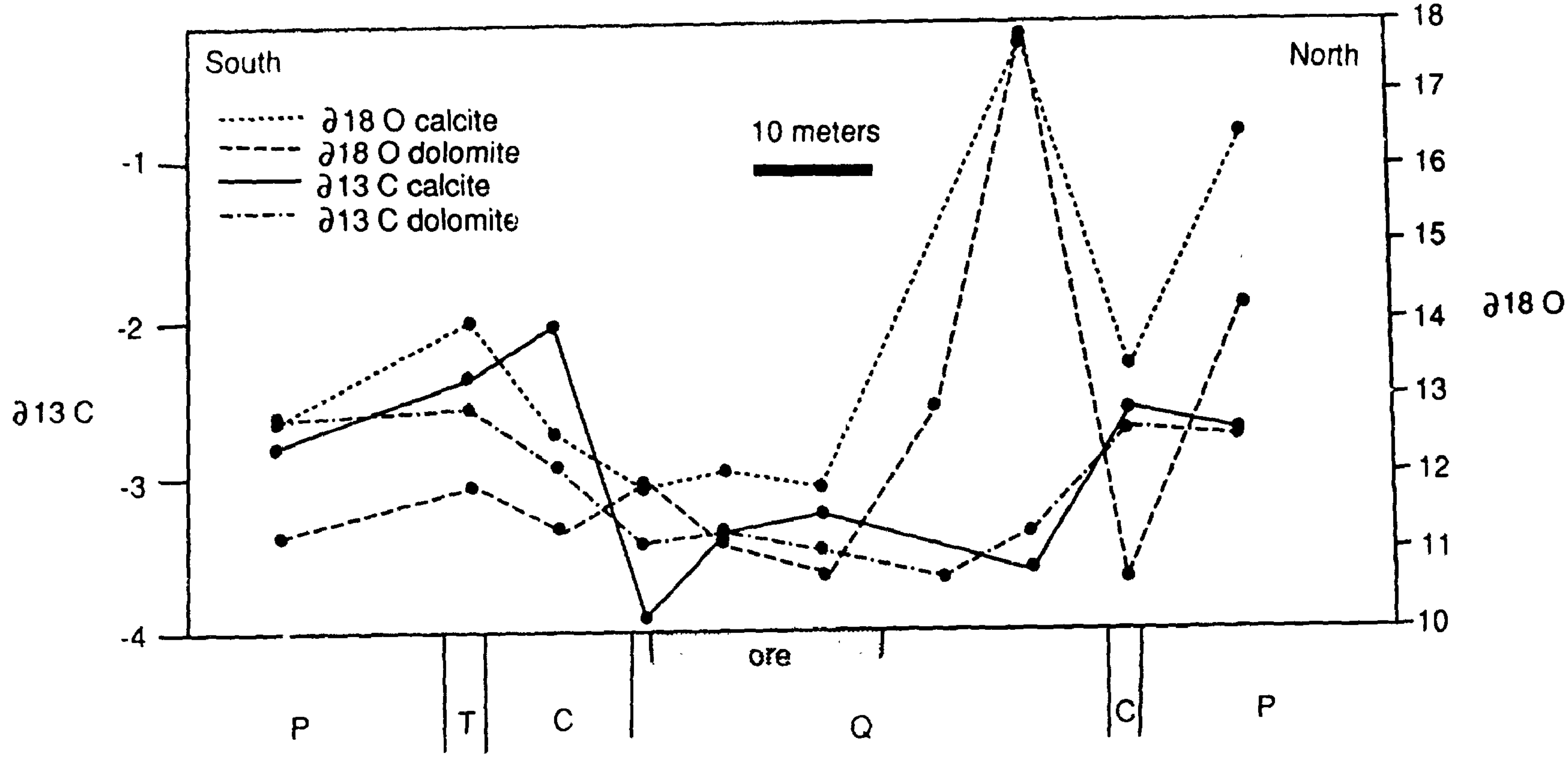

South
North
∂18 O calcite
∂18 O dolomite
∂13 C calcite
∂13 C dolomite
10 meters
∂13 C
∂18 O
-1
-2
-3
-4
18
17
16
15
14
13
12
11
10
ore
P
T
C
Q
C
P

Table 4-1. Carbon and oxygen isotopic abundances in dolomite and calcite from the Ropes deposit, from a south to north traverse through the Ropes deposit, as plotted in figure 4-1.

	Calcite		Dolomite/ferroan dolomite	
Sample#	**∂^{13}C**	**∂^{18}O**	**∂^{13}C**	**∂^{18}O**
R-51	-2.76	12.79	-2.63	11.33
R-50	-2.34	14.09	-2.54	11.94
R-49	-2.00	12.54	-2.93	11.33
R-48	-3.96	11.84	-3.44	11.91
R-47	-3.38	12.03	-3.36	10.99
R-42	-3.29	11.81	-3.50	10.75
R-43	-----	-----	-3.67	12.92
R-44	-3.61	17.71	-3.37	17.97
R-45	-2.56	13.40	-2.70	10.63
R-46	-2.71	16.50	-2.78	14.39

greater within carbonate - quartz - chlorite rocks and carbonate - talc rocks, at -2.0 to -2.6, than in serpentinitic peridotite, where it is -2.7 to -2.8.

Overall, $\partial^{13}C_{carbonate}$ for rocks in the Ropes deposit is comparable to that of carbonate minerals associated with gold at Timmins (Fyon and others, 1983, 1984) in deposits not proximal to carbonaceous sediments, which have mean $\partial^{13}C_{carbonate}$ from -2.4 to -4.4 (table 4-2) (Colvine and others, 1984). The rather limited range of $\partial^{13}C_{carbonate}$ at the scale of the Ropes deposit may imply relatively uniform temperatures and redox states during deposition of the carbonate minerals (Kerrich, 1987).

The $\partial^{13}C$ is dependent on ambient T, Eh and pH during precipitation as well as on carbon isotopic composition of the carbon bearing species in solution (Ohmoto and Rye, 1979). Carbonate minerals are considered resistant to resetting of carbon isotopic signatures (Rye and Ohmoto, 1974), as indicated by tight clustering of $\partial^{13}C_{carbonate}$ in individual deposits and compliance in $\partial^{13}C_{carbonate}$ in coexisting calcite and dolomite (Kerrich, 1989b). Sources of carbon in the Ropes deposit are uncertain, because a $\partial^{13}C_{carbonate}$ of

Table 4-2. Carbon isotope abundances of hydrothermal dolomite and calcite from Archean gold camps for deposits not proximal to carbonaceous sediments (Fyon and others, 1983).

Location	$\partial^{13}C$ mean	range
Aunor	-3.7	-4.3 to - 2.5
Beaumont	-3.4	-4.1 to - 2.6
Buffalo Ankerite	-3.1	-4.3 to - 1.1
Canusa	-3.2	-3.4 to -3.0
Carshaw/Malga	-3.5	-4.3 to - 2.1
Davidson Tisdale	-3.1	-3.7 to -1.0
Delnite	-2.4	-3.3 to - 0.5
Dobell	-4.1	
Duval	-4.1	-4.6 to - 3.7
Faymar	-3.4	-3.7 to - 3.2
Kinch	-4.0	-4.4 to - 3.6
McEnaney	-4.2	-5.9 to - 2.9
Porcupine Triumph	-4.4	-4.9 to - 3.4
Vesicle - filling calcite	-1.5	-3 to 0

approximately -2.5 can be produced from many sources (table 4-3) (Colvine and others, 1984). Average $\partial^{13}C_{carbonate}$ for igneous, sedimentary and metamorphic rocks is approximately -5 (Ohmoto and Rye, 1979).

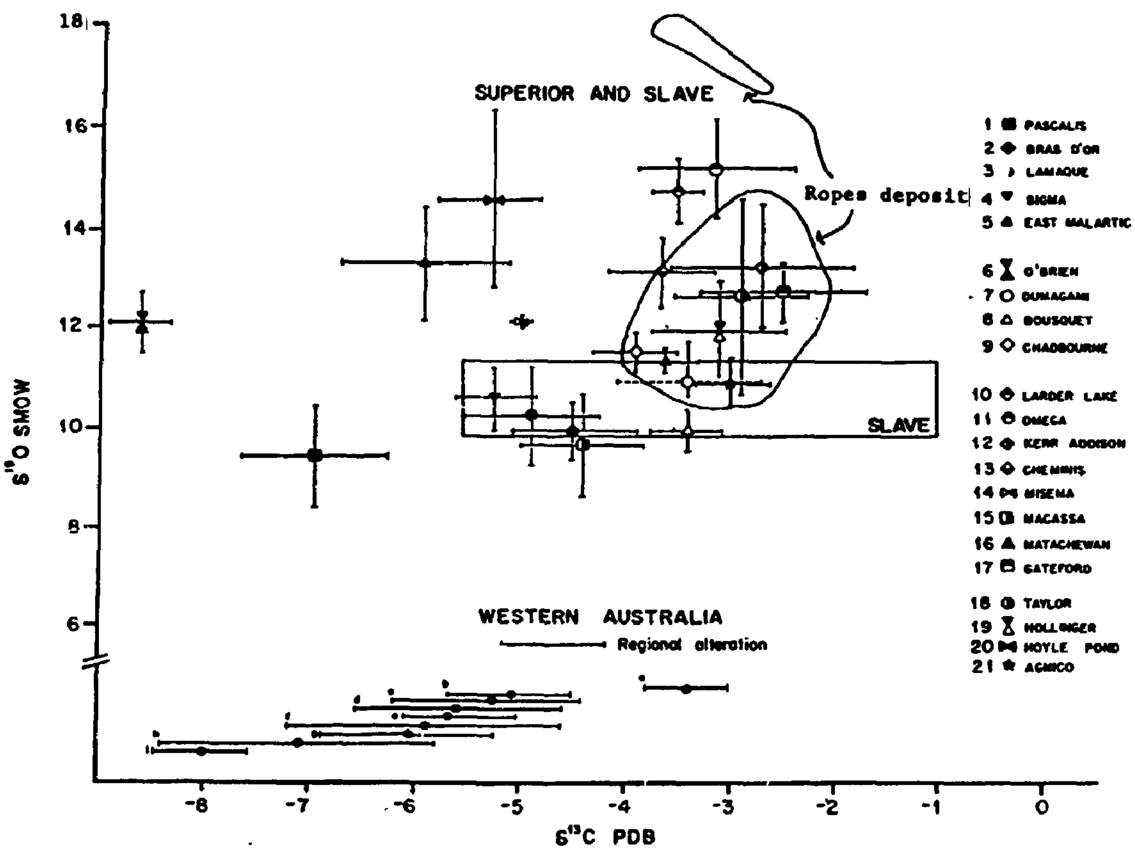
If $\partial^{13}C_{carbonate}$ in the Ropes deposit is related to temperature of deposition, then the lesser $\partial^{13}C_{carbonate}$ in the quartz - sericite - chlorite rock may indicate a higher temperature for deposition of this carbonate compared to the greater $\partial^{13}C_{carbonate}$ in the bounding carbonate - quartz - chlorite rock, carbonate - talc rock, and serpentinitic peridotite. Carbonate minerals in all these rocks are considered secondary, based on relict textures in rocks within the deposit, as presented in Chapter 3, which do not indicate carbonate rich protoliths, and on the presence of less altered strike extensions of these rocks outside the deposit which contain negligible carbonate. If carbonate minerals were deposited at higher temperatures within the quartz - chlorite - sericite rock, then this tabular trend of rock may have acted as the conduit for hydrothermal fluids.

Table 4-3. Possible carbon reservoirs, with corresponding carbon isotopic compositions, which could have contributed CO_2 to Archean hydrothermal fluid systems (Colvine and others,1984).

Reservoir	$\partial^{13}C(PDB)$
Magmatic	-5 ±2
Seawater	0
Marine Carbonate	0±3
dissolution:	
Calcite + 2H+ = H_2CO + Ca++	0
decarbonatization:	
3 Dolomite + 4 Quartz + H_2O = Talc + 3 Calcite + 3 CO_2	+3 to +5
Organic Compounds	-20 to -35
oxidation:	
$C + O_2 = CO_2$	<-10
hydrolysis:	
$2C + 2 H_2O = CO_2 + CH_4$	< -10

$\partial^{18}O_{dolomite}$ for rocks in the Ropes deposit, expressed in parts per mil relative to SMOW, ranges from 10.6 to 18.0 (figure 4-1; table 4-1). The pattern for calcite mimics the dolomite at generally slightly greater $\partial^{18}O$ (figure 4-1). $\partial^{18}O$ for both dolomite and calcite vary erratically across strike within both non auriferous quartz - sericite - chlorite rock and serpentinitic peridotite, carbonate - talc rock, and carbonate - quartz - chlorite rock, but are relatively consistent for both calcite, at $\partial^{18}O$ = 11.8 to 12.0, and dolomite, at $\partial^{18}O$ = 10.7 to 11.9, within or near ore zones in quartz - sericite - chlorite rock (figure 4-1). $\partial^{18}O$ for carbonate minerals is within the range for Archean lode gold deposits (Kishida and Kerrich,1987), although a few samples from the Ropes deposit fall toward higher $\partial^{18}O$ (figure 4-2). The common wide spread in $\partial^{18}O_{carbonate}$ in Archean gold deposits has been interpreted as evidence for varied degrees of re - equilibration at temperatures lower than the ambient conditions of original precipitation. Carbonate minerals are less resistant than quartz to retrograde oxygen isotope exchange (Clayton and others, 1968). It is common for calcite to be systematically enriched in ^{18}O relative to coexisting dolomite (Kerrich, 1987), and this is evident in the Ropes deposit (figure 4-1).

Figure 4-2. Average C and O isotopic abundances of hydrothermal ferroan dolomite or calcite from mesothermal gold deposits in the Superior and Slave provinces and Western Australia (after Kerrich, 1989a). Range for dolomite and calcite of the Ropes deposit is plotted.



SUPERIOR AND SLAVE
Ropes deposit
SLAVE
WESTERN AUSTRALIA
Regional alteration
$\delta^{18}O$ SMOW
$\delta^{13}C$ PDB
18
16
14
12
10
8
6
-8
-7
-6
-5
-4
-3
-2
-1
0
1 PASCALIS
2 BRAS D'OR
3 LAMAQUE
4 SIGMA
5 EAST MALARTIC
6 O'BRIEN
7 DUMAGAMI
8 BOUSQUET
9 CHADBOURNE
10 LARDER LAKE
11 OMEGA
12 KERR ADDISON
13 CHEMINIS
14 MISEMA
15 MACASSA
16 MATACHEWAN
17 GATEFORD
18 TAYLOR
19 HOLLINGER
20 HOYLE POND
21 AGNICO

Taken in conjunction, the $\partial^{13}C$ and $\partial^{18}O$ for carbonate minerals from the Ropes deposit fall toward the upper end of the $\partial^{18}O_{carbonate}$ versus $\partial^{13}C_{carbonate}$ field for Archean gold deposits (Kishida and Kerrick, 1987) (figure 4-2).

4.2 Fluid Inclusion Characteristics

Earlier studies (Shepeck, 1985) defined two populations of fluid inclusions with median homogenization temperatures of 265° C and 315° C in quartz veins. These veins possibly are auriferous, based on textural descriptions, but no assays support whether they are actually auriferous, or from within ore zones. Quartz from later stage, less deformed barren veins had only fluid inclusions which homogenized below 235° C. These inclusions are along fractures and homogenized at temperatures, uncorrected for pressure, of between 130° and 180° C. Homogenization temperatures for fluid inclusions in dolomite veins are between 215° and 250° C (ibid.). Most inclusions average 0.005 mm diameter, are a wide variety of shapes, commonly are along fractures and cleavage planes, and contain two phases, gas and liquid, with 15 to 20% gas by volume (Shepeck, 1985).

The present study characterized distribution and types of fluid inclusions in quartz - sericite - chlorite rock largely from within ore zones at the Ropes deposit. Two major types of secondary quartz are discernable from populations of fluid inclusions within the quartz: 1) Most quartz has ubiquitous small inclusions of highly variable composition. The quartz is recrystallized, has embayed grain boundaries, and many inclusions are concentrated toward grain boundaries. These characteristics are typical for quartz that forms in deep metamorphic environments at depths greater than 3 km. (J. Reynolds, Fluid Inc., personal communication, 1988). 2) Less common, clear, subhedral quartz has sparse planes of secondary inclusions. It is intergrown with ore stage pyrite and other sulfides and is confined to ore. Unquestionable primary inclusions were not observed in the clear quartz. Filling temperatures and compositions could possibly be obtained from the secondary inclusions, which are along planes in the clear quartz, but this would only provide constraints on the conditions under which these clearly secondary inclusions formed, because secondary inclusions by definition cannot be positively related to the geologic conditions under which the host quartz formed. Preliminary observations support a hypothesis that clear quartz and ore stage sulfides post date earlier cloudy metamorphic quartz and perhaps formed during the uplift part of the geologic history of these rocks after burial in the deeper metamorphic environment.

It is possible to distinguish ore stage quartz from apparently earlier, deep metamorphic quartz, and a more complete study may locate primary fluid inclusions in the clear ore-stage quartz. Examination of fifteen uncovered thin section samples, 100 microns in thickness, from zones of greater gold concentration within the orebody might allow interpretation of the fluid inclusion - host mineral relations and acquisition of temperature and composition data from which the composition of ore forming fluids might be inferred.

4.3. Age Determinations

A K - Ar age of 1752 +/- 58 million years was determined on sericite from a sample of sericite - quartz - chlorite rock with pyrite from the Ropes main ore zone (appendix A). A lower than expected potassium value for sericite probably indicates several percent quartz contamination, which has no effect on age, but leads to a slightly larger analytical uncertainty (T. M. Bills, K-Ar Lab Manager, Geochron Laboratories, personal communication). The age of 1752 +/- 58 million years may reflect resetting of the K-Ar geochronometer caused by Ar loss during: 1.) Penokean age metamorphism caused by collision of the Wisconsin magmatic terrane volcanic arc with the continent to the north at approximately 1860 to 1830 million years; 2.) intrusion of anorogenic A - type granites at approximately 1733 million years (Schulz, 1989); or 3.) widespread regional metamorphism, apparently unaccompanied by magmatic products in northern Michigan, which is documented by thermal resetting of Rb-Sr whole rock isotopic ages at 1650 to 1700 million years (Van Schmus, 1976; Peterman and others, 1985; 1986).

Two samples of galena from quartz veins in the Ropes main ore zone have common Pb model ages of 2418 and 2406 million years (Bornhorst, T., Michigan Technological University, 1988, personal communication). These ages contrast with common Pb ages of 2056 million years for galena from the Silver Creek prospect and 2050 to 2100 million years for galena from the Holyoke and Silver Mine Lakes areas (ibid.). The younger ages from the Silver Creek - Holyoke - Silver Mine Lakes areas may record rifting and fluid migration attendant to the initial development of the basins which host the Early Proterozoic Marquette Supergroup.

4.4. Carbonate and Alkali Saturation Indices

In the Ropes main ore zone there is not a unique spatial correlation between ore and carbonate saturation (appendix A) (Kishida, 1984), because there is both relatively high (>0.5) and low (near zero) carbonate saturation within the quartz - sericite - chlorite rock that hosts ore (figure 4-3b, c). East of the Ropes main ore zone the carbonate saturation is also near zero within quartz - sericite - chlorite rock (figure 4-3a).

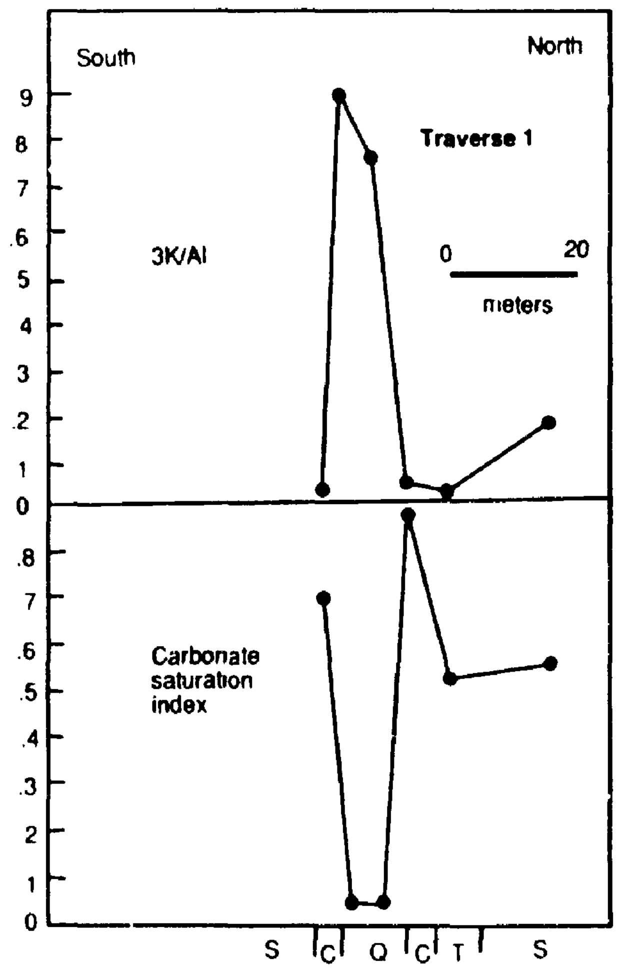
At Ropes, K is present mostly in sericite, therefore, a direct comparison of the K content of rocks indicates the absolute amount of sericite, which in turn depends on the Al content of the rock available for the formation of sericite. The alkali saturation index (Kishida, 1984) 3K/Al is generally greater than 0.5 within the quartz-sericite-chlorite rock regardless of whether it is ore, and generally less than 0.1 in the other rock types, with minima in the carbonate - quartz - chlorite rock (figures 4-3a, b, c). Increases in 3K:Al therefore correlate only with the presence of quartz - sericite - chlorite rock, but not uniquely with the presence of ore.

Figure 4-3. Carbonate and alkali saturation indices for threa north trending traverses through the Ropes deposit. Rock types noted along bottoms of diagrams are S = serpentinitic peridotite, T = carbonate - talc rock, C = carbonate - quartz - chlorite rock, Q = quartz - sericite - chlorite rock.

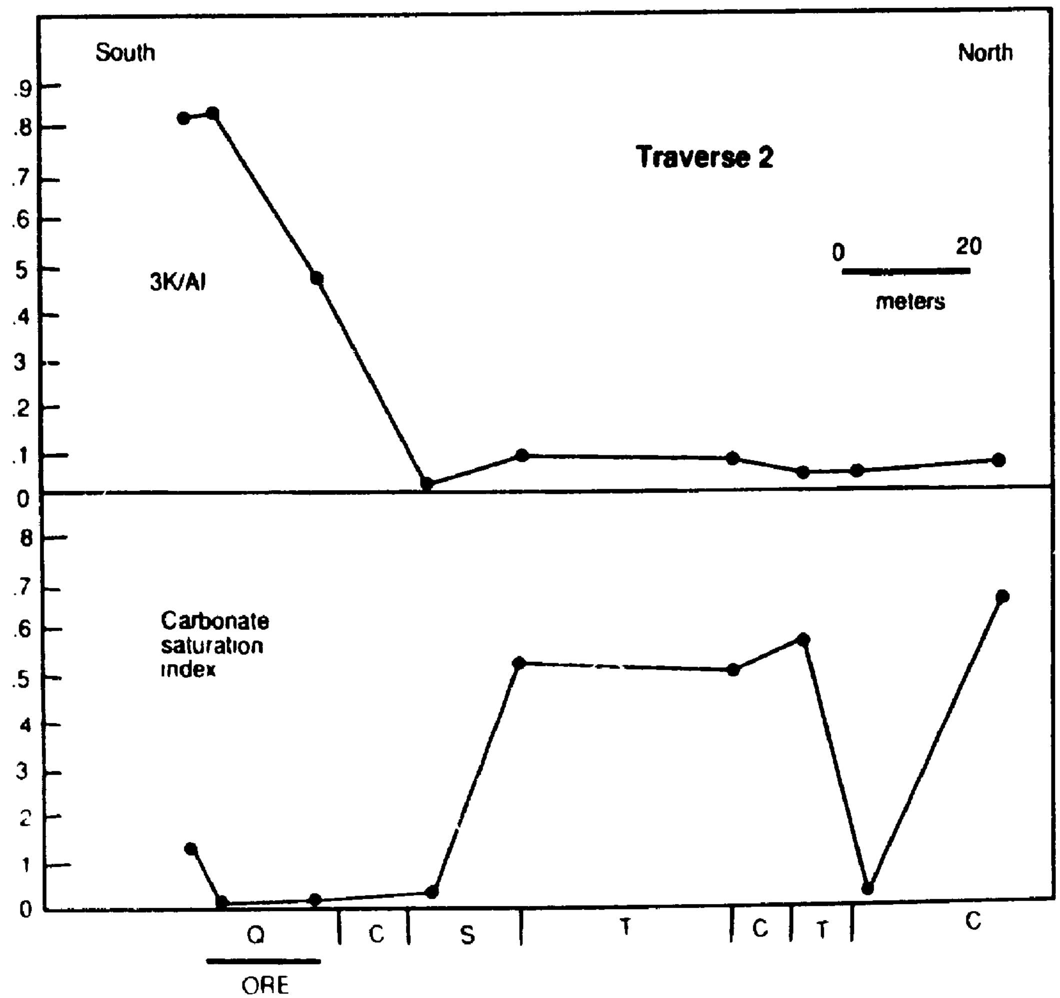
a. Traverse 1 = 250 m east of main ore zone

b. Traverse 2 = east end of main ore zone

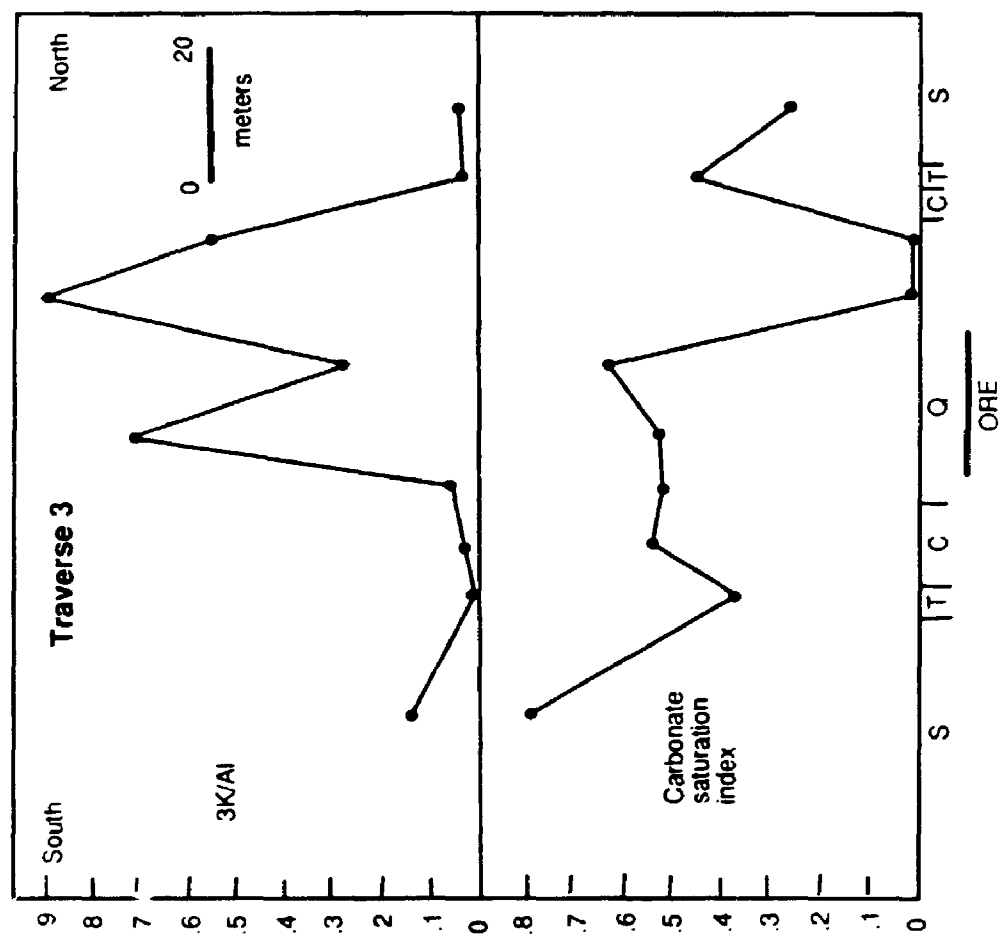
c. Traverse 3 = west end of main ore zone a.


South
North
Traverse 1
0
20
meters
3K/Al
Carbonate
saturation
index
9
8
7
.6
5
4
3
.2
1
0
.8
7
.6
.5
.4
.3
2
1
0
S
C
Q
C
T
S

b.


South
North
Traverse 2
0
20
meters
3K/Al
Carbonate saturation index
.9
.8
.7
.6
5
.4
3
.2
.1
0
8
.7
.6
.5
4
3
2
1
0
Q
C
S
T
C
T
C
ORE

c.


Traverse 3
South
North
3K/Al
Carbonate saturation index
0
20
meters
S
T
C
Q
C
T
S
ORE
9
8
7
6
5
4
3
2
1
0
.8
.7
.6
.5
.4
.3
.2
.1
0

CHAPTER 5 DISCUSSION

5.1 Marquette Greenstone Belt: Comparison With Other Archean Terranes

5.1.1 Models for the Origin of Greenstone Belts

There are four major lithostratigraphic associations within granite - greenstone subprovinces in the Archean Superior province of Canada. These are quartz - arenite and carbonate bearing shelf sequences deposited on older crust, mafic to ultramafic ocean plain sequences, mafic to felsic arc volcanic rocks, and late stage Timiskaming - type sequences of fluvatile sedimentary rocks and calc - alkalic to alkalic volcanic rocks formed in strike slip pull - apart basins. (Thurston and Chivers, in press).

Most of the Marquette greenstone belt is probably a mafic ocean plain sequence, with massive and pillowed basalt, minor rhyolite, and minor graphitic argillite as evidence for deep water sedimentation; this is particularly the case for the Mona, North, and Silver Mine Lakes blocks.

The Bjork - Lundeen and Kitchi blocks may have originally been a continuous southeast younging sequence, with an internal transition from basalt to dacite tuff. That these rocks were originally a continuous volcanic cycle is supported by the occurrence of glomerophyric basalt near the top of the basalt section below the dacite tuffs, a common occurrence in many tholeiitic basalt to calc - alkalic felsic volcanic rock cycles in Archean greenstone belts (Green, 1975). The Bjork - Lundeen and Kitchi blocks are possibly correlative with the mafic to felsic arc volcanic rock lithostratigraphic association, because thick tuffs and tuff breccias of the Kitchi block may indicate a constructional volcanic edifice, which characterizes this type of terrane.

The Deer Lake Peridotite could represent ultramafic magma intruded and serpentinized along a transform fault (Nesbitt and Muehlenbacks, 1988), or alternatively it may be obducted lower oceanic crust.

Conglomerate, arkose, graywacke, and slate of the Reany Creek block may be a Timiskaming - type late stage strike slip basin. The Reany Creek block is locally bound by shear zones, strikes with slight discordance to the trend of Archean volcanic rocks, and contains locally derived basalt and slightly auriferous pyritic banded iron formation clasts in its basal conglomerate. Vertically plunging folds (Small and Bornhorst, 1988) are compatible with strike slip movement.

The Marquette greenstone belt has characteristics of a rift phase greenstone belt, according to criteria defined by Groves and others (1987), in that it is structurally bounded blocks and is approximately 2.7 Ga in age. Shear zones separate the geologic blocks. Younging directions in some of the blocks are opposed across these structures and indicate tectonic juxtaposition of terranes.

Although modern high precision U-Pb zircon radiometric age determinations are lacking in the belt, there are a few 2.70 to 2.65 Ga U - Pb zircon radiometric age determinations on rhyolite sills, which are late in the sequence of greenstone belt volcanism, and 2.70 Ga ages on surrounding granite and tonalite gneisses in the Northern complex. These ages agree with the approximately 2.70 to 2.69 Ga youngest ages of volcanism in the Batchawana and Shebandowan greenstone belts, and the 2.668 to 2.684 ages of granitoid rocks surrounding the Gamitagama, Batchawana and Shebandowan belts of the southern part of the Superior province in Canada (Colvine and others, 1988).

Rift phase greenstone belts, which include the ..bitibi belt of Canada, host many of the largest and most abundant gold deposits, in contrast to generally less prospective older platform phase greenstone belts (Groves and others, 1987). The lenticular style of granite and greenstone terranes characteristic of the Superior province may have resulted from arc and micro continent collisions (Burke and others, 1976). A recent model, supported by extensive high precision radiometric age determination work, proposes development of these late Archean terranes by proccesses analogous to modern plate tectonics, with successive accretion of terranes (Thurston and Chivers, in press). Some Archean greenstone belts have been interpreted as analogous to modern marginal basins

(Tarney and others, 1976). Greenstone belts were previously considered sheet like shield volcanoes deposited on preexisting sialic crust, with deformation of the belt and diapiric rise of surrounding tonalites resulting from gravitational instability of basalt overlying less dense sialic crust (Gorman and others, 1978).

5.1.2 Orientation of Compression in the Late Archean

Regional as well as some deposit scale late Archean structures within and peripheral to the Marquette greenstone belt are compatible with northwest - southeast directed compression. This is in agreement with the inferred orientation of compression for the southern part of the Superior province in Canada (Colvine and others, 1988), and for the Vermillion greenstone belt in Minnesota (Hudleston and others, 1987, 1988; Southwick and others, 1989). Local examples in and near the Marquette greenstone belt include dextral shear on part of the Great Lakes tectonic zone south of Marquette, which is the major late Archean structure of this area (P. K. Sims, U. S. Geological Survey, personal communication, 1989), as well as a component of dextral shear indicated by ore related structural elements in the Ropes deposit.

The angular relationship of the two sets of ductile shears, in contrast to brittle shears (Anderson, 1951), is that the obtuse angle between the shears faces the greatest shortening direction (Ramsey and Huber, 1983). This is consistent with northwest - southeast shortening relative to the observed 058° and 107° structures in the Marquette greenstone belt. Shear zone related gold occurrences in the Bjork - Lundeen block, such as the east southeast trend of the Bjork - Lundeen quartz veins, and the east northeast trend of oblique shear veins and zones of greater gold concentration with dispersed pyrite in the Ropes deposit, are consistent with these directions. There is a greater density of lineaments, traceable on aerial photographs at approximately 1:10,000 scale, in both the Bjork - Lundeen and Silver Mine Lakes blocks compared to the remainder of the greenstone belt and to the surrounding Lower Proterozoic rocks (Lehnertz, 1987). This two - to three - fold increase in lineaments appears to correspond to a greater fracture density in the rocks in these parts of the greenstone belt. A possible explanation is that many shear zones contain a later brittle fracture system with the same general orientation as earlier ductile shears, and these late fractures may create the most obvious present day topographic effects (Osmani and others, 1989). A greater number of fractures would provide a greater number of channelways for gold bearing solutions to account for the greater number and larger size of gold occurrences in the Bjork - Lundeen and Silver Mine Lakes blocks. The 058° and 107° lineament directions are not as abundant in the surrounding Proterozoic rocks, and where they do occur, they commonly are along the projection of known structures in Archean rocks, and may be reactivated. Many gold deposits in the southern Superior Province of Canada have a similar relationship to regional and local structures (Osmoni and others, 1989; Poulsen and others, 1989).

The Marquette greenstone belt is on the southernmost edge of Superior Province and has been subjected to later tectonic events, including Early Proterozoic rifting, Early Proterozoic compression during the Penokean orogeny, and Middle Proterozoic Keweenawan rifting. Major Archean structures such as the Dead River and Carp River Falls shear zones were reactivated in Early Proterozoic time, both as bounding, probably listric normal, faults during extension coincident with deposition of the Marquette Supergroup, and later as high angle reverse structures during north northeast - south southwest oriented compression.

5.1.3 Source of Gold at the Scale of the Greenstone Belt

Recent workers have considered the source requirements needed to derive all ore components, including gold, from the devolatilization of lower mafic parts of greenstone belts at amphibolite facies (Phillips and others, 1987) or granulite facies (Cameron, 1988). Approximately 5 wt.% structural water, and volatiles including CO_2 are released from a hydrated mafic rock at the transition from greenschist to amphibolite facies (Kerrich and Fyfe, 1981). Breakdown of hydrous minerals, carbonate minerals, and sulphides could provide a near neutral reducing fluid capable of leaching gold and other elements from the greenstone sequence (Ho and others, 1985). Crustal scale fault and shear zone systems in this model focus fluid flow toward suitable host rocks and structural sites, and temperature decline below the amphibolite facies - greenschist facies transition is proposed as a mechanism for gold deposition. Neither special gold enriched source rocks nor unreasonably large volumes of greenstone belt rocks are required (Phillips and others, 1987). Background gold contents of most igneous rocks range from 2 to 5 ppb (Tilling and others, 1973; Kwong and Crocket, 1978; Sabor and others, 1982; Keays, 1984).

An average gold concentration of approximately 3 g/tonne in the Ropes deposit is an enrichment of approximately 10^3 times above background, if the initial gold concentration in greenstone belt rock considered as source rock for the Ropes deposit was 2 ppb. The gold content of the Ropes deposit is approximately 10 tonnes, therefore the deposit would require approximately 6.6 km^3 of greenstone belt rocks as a gold source, assuming an efficiency of 50% for extraction of gold from the source rocks and an efficiency of 50% for deposition of gold in the host rock. This represents a volume of rock equal to a cube approximately 2 km on a side.

Most gold occurrences in the Marquette greenstone belt, including all known occurrences with drill indicated resources, are within greenschist facies rocks. The Ropes mine is in greenschist facies rocks approximately 1.5 km stratigraphically above upper greenschist facies rocks and the bounding Compeau Creek Gneiss in the far southwest part of the belt. Gold occurrences in the southwest facing Silver Mine Lakes block are likewise in greenschist facies rocks 0.5 to 1 km south of amphibolite facies rocks of the North block. Rocks are at higher metamorphic grade to the north, although the setting is complicated by structural contacts, intrusion of sills, and local cover by Lower Proterozoic rocks. Therefore many of the gold occurrences in the belt may be in similar positions in the volcanic sequence above the transition from amphibolite to greenschist facies.

5.2 Ropes Deposit: Comments on Geologic Setting and Style of Gold Concentration

5.2.1 Position of the Ropes Deposit in the Volcanic Framework of the Belt

Many Archean lode gold deposits in the Superior province of Canada are proximal to late accumulations of sedimentary rocks (Gill, 1948; Butler, 1987; Colvine and others, 1988; Thurston and Chivers, in press). The exact position of the Ropes deposit in relation to the volcanic succession in the southwest part of the Marquette greenstone belt is difficult to assess because of emplacement of the Deer Lake Peridotite (DLP), but the deposit is near the uppermost part of the Bjork - Lundeen block near minor accumulations of graywacke and banded iron formation. Tuff breccias of the Kitchi block to the southeast of the DLP have characteristics consistent with an origin as mass flow deposits such as mudflow breccias. Although these tuff breccias do not have the well developed fluvatile or turbiditic features characteristic of sedimentary rocks found in many volcanic - sedimentary breaks within Archean greenstone belts, they are sedimentary rocks in the sense that some are likely the products of mass wastage of dacite flows and tuffs similar to the volcanic rocks immediately west of the Ropes deposit. Therefore the Ropes deposit may be near a volcanic - sedimentary break, if a break is defined as a tectonically modified transition from volcanic rocks to sedimentary rocks within a greenstone belt, with evidence of early tectonic control of sedimentation. The Bjork - Lundeen block may have originally underlain the Kitchi block prior to emplacement of the Deer Lake Peridotite, as appears likely from the common rock types and younging directions in adjacent parts of the Bjork - Lundeen and Kitchi blocks. The interface between two interlayered and therefore partly coeval major volcanic facies, basalt and dacite, may have been a zone of crustal weakness which also facilitated intrusion of the peridotite. The Ropes deposit is apparently hosted by a minor east northeast striking shear zone splay off a more major northeast striking shear zone developed within and along the northwest margin of the peridotite. The presence of a probable lamprophyre in the Ropes deposit is compatible with its proximity to a crustal - scale structure. This inferred crustal scale structure may have controlled emplacement of the Deer Lake Peridotite and facilitated access of lamprophyric melts generated from the mantle (McNeil and Kerrich, 1986; Rock and Groves, 1988; Wyman and Kerrich, 1989).

5.2.2 Role of the Deer Lake Peridotite

Composition of the Deer Lake Peridotite (DLP) is compatible with generally accepted ranges of composition for ultramafic komatiites (Arndt and others, 1977; Arndt and Nisbet, 1982), in that it has MgO > 18% and < 40%, TiO_2 < 1%, Ni > 100 ppm, and Cr > 140 ppm, with the exception that CaO/Al_2O_3 varies greatly both above and below the 0.8 - 1.1 range indicated for komatiites (ibid). However, the DLP does not satisfy the physical volcanologic criteria for komatiites in that lavas with spinifex textures are not present (Naldrett and Cabri, 1976). Although it was not extrusive, the DLP may represent magma of komatiitic affinity, although some Alpine type peridotites may also plot in komatiitic compositional fields (Naldrett, 1981).

The DLP has relatively more chrysotile in serpentinitic peridotite which retains relict cumulate textures, compared with greater abundance of antigorite along foliated zones in serpentinite (Rossell, 1983) This is compatible with early serpentinization of the Deer Lake Peridotite (DLP) below 300° C to form chrysotile, followed by higher temperature alteration during shear deformation under greenschist facies conditions to form antigorite (Arndt and others, 1977). At low temperatures, dissolution of primary minerals in peridotite can occur rapidly relative to precipitation of hydrous mineral phases, favoring constant volume alteration and preservation of textures, whereas at higher temperatures and pressures appreciable increases in volume are more likely because of the increased rate of precipitation of less dense hydrous minerals, with resultant destruction of textures (Nesbitt and Bricker, 1978).

Many instances of Au concentrations are known within or near the margins of ultramafic rocks, for example with Archean komatiites (Anhaeusser, 1976; Pearton, 1982) and also with carbonatized ultramafic massifs (Zhelobov, 1979; Pipino, 1980; Gresens and others, 1982). CO_2 rich fluids, possibly with gold as carbonyl or carbonate complexes, may promote carbonate forming reactions in ultramafic rocks, which could lower P CO_2 of the fluid, decrease its acidity, and induce precipitation of gold. (Kerrich and Fyfe, 1981). Serpentine is unstable in the presence of $C0_2$ rich fluids and breaks down to form magnesite and talc (Deere and others, 1977). Rossell and Kalliokoski (1983) concluded that carbonate - talc alteration at the Ropes deposit resulted from addition of CO_2, Ca, and Al and removal of H_2O and Mg from the serpentinite, using mass balance methods and assuming constant volume serpentinization, because of the common preservation of relict magmatic textures. Early carbonate veins in serpentinitic peridotite are pseudomorphic after cross - fiber chrysotile, indicating that carbonatization may have followed serpentinization. The early veins are cut by coarse grained massive white dolomite veins.

Carbonate - quartz - chlorite rock in the Ropes deposit is analogous to listwaenites (Buisson and LeBlanc, 1985; 1986), carbonate rich rocks along borders of ultramafic massifs which are interpreted as the product of carbonatization of ultramafic rocks (Labochinkov, 1936; Bok, 1956; Pleshko, 1963). These green and gray rocks are Mg, Fe and Ca carbonate minerals with quartz, Mg - chlorite, accessory talc, serpentine and minor magnetite and chromite. They are generally along tectonic contacts and grade laterally into serpentinitic ultramafic rocks through a carbonate - talc zone. These contacts were commonly channelways for hydrothermal fluids which carbonatized the ultramafic rocks during later stages of emplacement.

The DLP was not likely a source of gold for the Ropes deposit. Rossell (1983) determined that gold contents are less in the serpentinitic peridotite, averaging 2.8 ppb, with a range of 1 to 4 ppb, than in carbonate - talc rock where gold averages 3.4 ppb, with a range of 1 to 11 ppb. This suggests that gold was added, not removed, from the DLP during carbonate - talc alteration.

5.2.3 Controls on Localization of the Deposit

5.2.3.1 Control by Structures

The inferred northeast trending crustal scale structure re-resented by the major transition from basalt to dacite, along which the Deer Lake peridotite is emplaced, may be a first order control. The o.erall site of the Ropes deposit was localized by competency contrasts along contacts between serpentinitic peridotite and dacite, which facilitated simple shear during northwest - southeast oriented compression.

The specific site of the Ropes deposit is controlled by an 080° striking dilational bend in the 070° striking, near vertical shear zone. Asymmetric fabrics and structures include S - C and S - C' fabrics, foliation slightly oblique to the overall strike of the shear zone, arrangement of right stepping en echelon auriferous oblique shear veins and similarly oriented zones of gold concentration with dispersed pyrite, and local steep east plunging mineral lineation in the schistosity. These features indicate a north side down, oblique dextral sense of movement on the zone, with deformation by simple shear strain. Although flattening of primary volcanic features in rocks of the greenstone belt indicate that shear zones developed in an overall compressional regime, the immediate environment at Ropes involved local dilation. Formation of both auriferous oblique shear veins and zones of gold concentration with dispersed pyrite was synchronous, based on their similar geometry and on the observation that some of the higher grade zones of gold concentration with dispersed pyrite locally extend eastward from old stopes marking the location of vein systems mined during the late 1800's. The trend of quartz - sericite - chlorite rock which hosts the Ropes deposit narrows toward surface and toward the east, and this constriction may also have focussed hydrothermal fluids.

The overall concentric, convex to the east geometry of the major ore subtypes in the main ore zone, combined with the gradual western cutoff of gold concentrations, and the sharp eastern cutoff, suggest that the flow vector for mineralizing fluids, relative to the present day surface, may have been upwards from the deep southwest part of the deposit, Zoning of ore subtypes in the Ropes deposit is consistent with fluid flow moving from the direction of the inferred major structure along the margin of the Deer Lake Peridotite west of the deposit, toward the east northeast. Movement along the inferred major structure which controls the distribution of the basalt and dacite facies and localizes the peridotite, could have provided a seismic pumping action to assist in moving hydrothermal fluid. Several dextral offsets along this margin of the peridotite suggest that slip was oriented simiarly to that inferred at the Ropes deposit.

Many gold deposits in the Superior province are high angle reverse faults characterized by reverse - oblique shearing (Roberts, 1987). These faults were unfavorably oriented relative to later imposed stress and required high fluid pressures to facilitate movement (Sibson and others, 1988). The Ropes deposit is in a structure which dips steeply south at surface but vertically at depth. Movement was north side down with a dextral component. Therefore, it is a high angle reverse fault, at least in its uppermost part.

In many Archean Superior province gold deposits, nearly flat lying auriferous veins are present, and are interpreted to indicate that fluid pressure in these deposits periodically exceeded lithostatic pressure, resulting in episodic tensile opening of veins because of build up of fluid pressure, followed by sudden release (Sibson and others, 1988; Bursnall, 1989; Sibson, 1989). Absence of auriferous flat lying veins in the Ropes deposit, and consistent orientation of asymmetric fabrics, suggests that movement there was more uniform and less episodic during deposition of gold. There are, however, nearly flat lying late barren carbonate veins in carbonate - talc rock, and these may indicate late brittle extension.

5.2.3.2 Control by Physical Properties of Rocks

Competency contrasts between rock types were one control on localization of the deposit. Dacite, altered to quartz - sericite - chlorite rock, was more brittle than carbonate - quartz - chlorite rock during simple shear deformation, as indicated by abundant millimeter scale quartz veinlets and by the heterogeneous distribution of better foliated zones in the former rock. Carbonate - quartz - chlorite rock, derived from serpentinitic peridotite, is adjacent to the deposit and was more ductile than quartz - sericite - chlorite rock, indicated by pervasive millimeter scale foliation,

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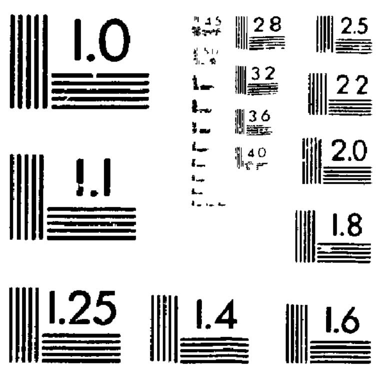

local S - C fabric, and obliteration of primary textures. Slightly more brittle behavior of the quartz - sericite - chlorite rock compared to the carbonate - quartz - chlorite rock promoted fracturing in the former rock, as indicated by the abundance of millimeter scale quartz veinlets, which increased the surface area available for reaction with fluids and may have promoted deposition of gold.

Mylonite is defined as "foliated rock, commonly lineated, generally containing porphyroclasts set in a finer grained matrix which is in planar zones. The matrix is an aggregate of daughter grains, the products of dynamic recrystallization, which are on the order of two orders of magnitude finer than their parent grains" (Hanmer, 1986). Recrystallization of quartz - sericite - chlorite rock at Ropes most commonly resulted in coarser grained quartz and sericite along foliation planes than was originally present in the matrix of the dacite tuff protolith, so it does not strictly satisfy these criteria. Parts of the very well foliated carbonate - quartz - chlorite and carbonate - talc rocks are dominantly sub 100 micron grain size with carbonate minerals and talc in preferred crystallographic orientation, and are mylonites according to the above criteria, because their protolith was peridotite with a much larger 1 to 3 mm grain size. Similar mylonitic textures have been noted in the Josephine peridotite (Norrell and others, 1989).

It has been suggested (G. Scott, personal communication, 1989) that the Ropes deposit is syngenetic with the enclosing rocks, because the overall trend of the main ore zone is nearly concordant with contacts between rock types, gold is with fine grained pyrite, and compositionally layered carbonate - quartz - chlorite rock is interpreted as chemical sedimentary rock. If the latter rocks were formed by chemical precipitation of carbonate minerals and quartz as laminated cherts in a surficial volcanic environment during hiatuses in volcanism, concurrent with introduction of gold, then they should contain relatively more gold than dacite tuff being deposited in the same environment, because the tuff represents rapid dilution of the system compared with the proposed chemical precipitation. This is not the case, because the altered dacite tuff has more gold than the proposed chemical sedimentary rocks. Neither are the carbonate - quartz - chlorite rocks a mix of dacite and peridotite debris, because abundances of rare earth elements and other less mobile trace elements indicate a peridotite protolith, not a mixture of two end members. Furthermore, the Deer Lake Peridotite lacks characteristics of extrusive komatiites, rather it is an intrusive igneous rock, based on preserved cumulate textures. Very fortuitous circumstances would be necessary to envelope an exhalative deposit within an intrusive setting. Alteration attendant to gold deposition affects the serpentinitic peridotite, which was therefore necessarily present prior to the time of gold concentration.

Sharp gradients in physical and chemical properties related to changes in rock type appear to control the location of many of the most significant gold occurrences in the Marquette greenstone belt. These are at or near contacts between rock types and include the Ropes deposit and the Peninsula, Pine Hill, Silver Creek West, and Silver Creek prospects (Chapter 2.3.4). At the Bjork - Lundeen prospect, which cuts layering of rock types at a high angle, gold concentrations are greatest in basalt and least where the veins cross medium grained gabbro.

5.2.3.3 Control by Composition of the Rocks

Abundances of rare earth elements and less mobile trace elements define only two major groups of rocks at Ropes, one group derived from volcanic rocks, dominantly dacite with minor basalt, and a second group derived from peridotite. Compositionally layered carbonate - quartz - chlorite rocks are part of this second group.

Deposition of gold in hydrothermal systems is commonly focussed along interfaces between solutions of contrasting chemical composition (Romberger, 1988; Fyfe, 1988). Serpentinitic peridotite is altered to carbonate - talc rock and carbonate - quartz - chlorite rock peripheral to the deposit, and therefore was a sink for CO_2, possibly contained in the gold bearing solution. Alteration of original feldspar in dacite tuff, now quartz - sericite - chlorite rock, possibly provided a sink for K. Ore in quartz - sericite - chlorite rock in the Ropes deposit is not rich in carbonate minerals, however, the original content of ferromagnesian and Ca - bearing minerals in a rock directly affects the maximum amount of CO_2 added during alteration, therefore the ultramafic serpentinitic peridotite was a more favorable sink for CO_2.

Gold bearing quartz - sericite - pyrite alteration zones in many Archean lode gold deposits commonly grade outward into broader chlorite - carbonate alteration zones, regardless of original rock type (Fyon and Crocket, 1982: Butler and others, 1987). In the Ropes deposit, this typical trend was enhanced by the presence of the dacite tuff protolith of the quartz - sericite - chlorite rock that hosts ore, which was initially relatively SiO_2 and K_2O rich compared to the bounding serpentinitic peridotite. The latter rock developed a greater proportion of carbonate minerals and chlorite during alteration because of its initially greater CaO and MgO contents.

5.2.4 Timing of Gold Deposition

Deposition of gold post dated volcanism, and emplacement and serpentinization of peridotite. It was coincident with simple shear deformation, as indicated by asymmetric fabrics and structures in the deposit; some of these are formed directly by ore. Early quartz in the Ropes deposit has characteristics compatible with its formation in the deep metamorphic environment, whereas later clear quartz is associated with ore stage sulphide minerals. At the

Peninsula prospect 3 km west of the Ropes deposit, gold concentrations are with zones containing late fracture - controlled ferroan dolomite. Chlorite partly replaces biotite only in these auriferous zones. These observations suggest that gold concentration in the Marquette greenstone belt post dated peak metamorphism. Peak metamorphism in the Marquette greenstone belt is represented by mafic volcanic rocks at amphibolite facies. These amphibolite facies rocks are distributed closest to the boundaries of the greenstone belt with the enclosing tonalitic gneiss. The gneiss is in intrusive relationship with the amphibolite facies volcanic rocks, and metamorphic grade decreases away from the contacts of the volcanic rocks with the gneiss. The thermal event associated with emplacement of the tonalitic gneiss therefore caused peak metamorphism in the belt. Therefore, gold deposition, because it appears to post date peak metamorphism, is also inferred to post date emplacement of the tonalitic gneiss.

5.2.5 Depth of Formation

Ore related structures and fabrics in the host rock are characteristic of the brittle - ductile transition. Ductile behavior is indicated by mylonitic fabrics, especially in carbonate - quartz - chlorite and carbonate - talc rocks. Brittle response is indicated by local breccias with angular fragments of previously veined and altered rock, by parts of the ore with random networks of millimeter scale quartz veinlets, and by a northeast striking, shallowly south dipping fault which displaces ore and is interpreted as a Riedel shear. Mineral asemblages in rocks within and surrounding the deposit are compatible with greenschist facies metamorphism. In combination, these criteria suggest that the deposit formed at depth of greater than 5 km, by comparison with similar brittle - ductile features and conditions of metamorphism documented in Superior province gold deposits in Canada, where independant estimates of temperature and pressure are available from isotopic and fluid inclusion studies (Colvine and others, 1988).

Kinematic indicators in many Archean gold deposits in the Superior province of Canada document high angle reverse or reverse - oblique slip (Bursnall, 1989). Veins in these deposits contain CO_2 rich, low salinity fluid inclusions, and have stable isotopic characteristics which suggest that the deposits developed at 250° to 400° C and 2 to 4 Kb (Kerrich, 1989). This represents depths of 7 to 14 km, corresponding to the base of the seismogenic regime, within the brittle to ductile transition at the roots of high angle reverse or reverse - oblique fault systems (Sibson, 1989).

Discharge of low salinity, CO_2 rich thermal water of possible metamorphic origin has been documented in a variety of modern collisional environments associated with major structures, including the Barbados accretionary wedge, the Franciscan complex of California, and the Alpine fault in New Zealand (Kerrich, 1989a). These may represent the surface expressions of hydrothermal systems of the type which generate mesothermal gold deposits at depth. Structurally aligned mercury districts in British Columbia are interpreted as higher level expression of fault controlled mesothermal gold systems (ibid).

5.2.6 Ore - Forming Fluids

Narrow ranges in C and O isotopic compositions of carbonate minerals in ore, and the simple mineral assemblages and narrow compositional ranges within the major rock forming minerals in solid solution series in the deposit, suggest that the hydrothermal circulation system that formed the Ropes deposit was sufficient in intensity and duration to promote an advanced state of mineralogic and isotopic homogeneity. Equilibration of rocks to the simple mineral assemblages and limited range of compositions of minerals is unlikely during regional greenschist facies metamorphism, because only a limited scale of diffusion, on the order of centimeters, is likely to occur in fine grained rocks under low grade metamorphic conditions (Best, 1982). The case at Ropes is in marked contrast, for example, to rocks enclosing the Bousquet gold deposit in Quebec, where there are complex mineral assemblages and wide variations in the composition of minerals in solid solution series, both on the hand specimen and deposit scale (Stone, 1988). Differences in composition of minerals in the Ropes deposit probably reflect in large part original differences in bulk composition between serpentinitic peridotite and dacite.

5.2.7 Comparison of Ropes with Other Deposits

The Ropes deposit has geometric and structural similarities with the Kremzar gold deposit on the north edge of the Wawa subprovince near Goudreau in Finan Township, although it differs in host rock and specific alteration minerals (Canamax Operations Group, personal communication). The B horizon at Kremzar is in a dilational sigmoidal vein system that trends oblique to contacts of the shear zone. En echelon lensoidal veins, referred to as siliceous ore, trend 30° to the shear zone boundaries. The Cheminis gold deposit east of Kirkland Lake, Ontario also has geochemical and structural similarities with the Ropes deposit. Carbonatized ultramafic volcanic rocks and fuchsitic agglomerate and conglomerate bound ore hosted by dacite crystal tuff, with the gold enclosed in pyrite grains (Clark and Bonner, 1987; Panagapko, D. A., Eldorado Resources, personal communication, 1987). Carbonate rich rocks at Cheminis similarly took up much of the deformation (Ayer, J. A., 1986). The Madsen deposit in Red Lake, northwestern Ontario is a mirror image of the Ropes deposit in terms of its structural setting, with sinistral shear indicated by left stepping oblique shear veins in a wedge shaped zone of tuff between ultramafic and felsic volcanic rocks (Hodgson, 1989).

CHAPTER 6 SEQUENCE OF EVENTS IN FORMATION OF THE ROPES GOLD DEPOSIT

Relative timing of volcanism, intrusion, development of structures, and gold concentration in the Ropes deposit and enclosing rocks follows:

1.) Volcanism during late Archean time was initially basalt, with contemporaneous gabbro feeder sills and dikes, partly coeval with, then followed by dacite tuff and tuff breccia. There was local reworking of volcanic rocks to form immature graywacke during a minor hiatus in volcanism coincident with the change from basalt to dacite. This was followed by local deposition of banded iron formation west of the present location of the deposit. Continued extrusion of dacite pyroclastic rocks, dacite flows, and equivalent dikes and sills followed. These are exposed in the northeast part of the Bjork-Lundeen block, together with compositionally equivalent rocks in the Kitchi block, which are at least partly reworked as mass flow deposits.

2.) Peridotite was intruded as a sill complex, with minor outlying sills in the enclosing volcanic rocks. The peridotite was wholly serpentinized, possibly coincident with its emplacement, but has generally well preserved serpentine pseudomorphs after primary olivine and pyroxene. Lesser abundances of TiO_2, Al_2O_3 and Sc relative to typical pyroxene rich ultramafic rocks suggest that primary mineralogy was dominated by olivine. This type of dense magma may have been less likely to reach surface. Diagnostic features of extrusive ultramafic komatiites, such as flow contacts, polysuturing, and spinifex textures are absent. Transformation of olivine to less dense serpentine caused volume increase which was accomodated by curvilinear hydration fractures without preferred orientation, filled by chrysotile asbestos.

The serpentinitic peridotite strikes east northeast at a slight angle to the overall northeast trending interlayered contact between basalt and dacite tuff in the southwest part of the greenstone belt. This major volcanic facies boundary may have provided a preexisting zone of weakness which facilitated access of peridotite from a mantle source either by intrusion or obduction, implying existence of a transcrustal fracture considered a terrane boundary.

3.) Planar fractures, with chrysotile orthogonal to their boundaries, cut curvilinear hydration fractures in serpentinitic peridotite.

4.) The volcanic - intrusive sequence was tilted by northwest - southeast oriented compression. Shortening formed brittle - ductile shear zones within and along the northeast striking serpentinitic peridotite and along sub parallel second order structures largely developed on preexisting zones of weakness, such as the contacts of the 070° to 080° striking trend of dacite tuff within serpentinitic peridotite at the Ropes location. Conjugate shears striking approximately 107° formed, for example, the Bjork-Lundeen prospect quartz veins located at a bend in the strike of the volcanic rocks from northeast to east northeast. There was dextral offset at the margins of the serpentinitic peridotite at several places.

The Ropes shear zone has an oblique dextral, north side down sense of movement with a minor dextral component, indicated by orientations of S - C fabric, S - C' fabric, and right stepping en echelon oblique shear veins. Offset of minor veins on the Bjork-Lundeen shear and offsets along the northwest margin of the serpentinitic peridotite are also consistent with a component of dextral slip. If these were formed during the same shortening, the compression which would simultaneously cause indicated dextral components of movement at these locations was oriented northwest - southeast.

Foliation is most pronounced in carbonate - quartz - chlorite rock which borders ore - bearing quartz - sericite - chlorite rock on north and south. The former rock was originally peridotite, indicated by abundances of less mobile trace, and rare earth elements, but retains no primary texture. Quartz - sericite - chlorite rock with well to poorly preserved primary volcanic textures has abundances of less mobile trace elements and rare earth elements compatible with a dacite tuff protolith. It was more brittle than the carbonate - quartz - chlorite rock during shear deformation.

Foliation in the Ropes deposit is inferred to be a tectonic schistosity because it is secondary minerals which locally cut relict primary features such as feldspar phenocrysts pseudomorphed by sericite, and lithic fragments. This is defined mainly by dimensional alignment of chlorite in carbonate - quartz - chlorite rock and sericite and chlorite in quartz - sericite - chlorite rock. Layered, auriferous, tetrahedrite bearing quartz veins with aligned schistose inclusions of sericite - quartz - chlorite wall rock are interpreted as en echelon right stepping oblique shear veins formed near the south side of the main ore zone. These veins formed concurrently with the zones of schistosity parallel gold concentration characterized by dispersed pyrite that are most centrally within the trend of quartz - sericite - chlorite rock. The zones of gold concentration trend 065° in their central parts but 070° nearer the contacts between rock types at the north and south sides of the deposit, where more movement was accomodated near contacts with more ductile carbonate - quartz - chlorite rock, and the 065° schistosity was flattened to the plane of shear, represented by the contacts between contrasting rock types, by continued movement.

Because mappable zones of gold concentration with dispersed pyrite, auriferous quartz-tetrahedrite veins, and alignment of sericite, chlorite, talc and locally fine auriferous pyrite follow schistosity, gold deposition and hydrothermal alteration were contemporaneous with simple shear deformation. Shear deformation continued until after at least early stages of gold deposition because auriferous fine pyrite locally has pressure fringes in the plane of the schistosity, and quartz in auriferous quartz veins is undulose, has cataclastic textures and is locally dimensionally aligned in the plane of schistosity. The main ore zone is situated in a 400 m long 080° trending part of an overall 070° trend of quartz - sericite - chlorite rock. The 080° part of the trend acted as a dilational bend, considering the indicated oblique dextral movement on the Ropes shear, facilitating access by hydrothermal fluids and causing dilational overriding which formed auriferous oblique shear quartz veins.

5.) A layer of microcrystalline carbonate quartz rock, which is not ore, developed internal to the quartz - sericite - chlorite rock, along the north side of the main ore zone, and parallel to 080° contacts between rock types. The granoblastic texture of this rock suggests that it formed late in the sequence of shear, perhaps by carbonate minerals and quartz deposited along a principal displacement or D shear.

6.) A 060° striking 20° south dipping reverse fault, which cuts the main ore zone below t'.e 900 level, developed in the orientation of a large C' structure or Riedel shear, with some clockwise rotation of the deeper block, possibly as silicification, or waning of the hydrothermal system with attendant drop in temperature, made the zone more brittle.

7.) Local crenulation is confined to the Ropes shear zone, where platy minerals are deformed into microbuckles generating a subhorizontal lineation in the plane of the schistosity. It represents a late minor brittle - ductile deformation within the shear zone.

8.) Ajibik Quartzite was deposited during Early Proterozoic time on an eroded Archean surface that was similar to the present day level of exposure, as indicated by numerous small inliers of Lower Proterozoic quartzite and graywacke preserved on the Archean surface throughout the greenstone belt.

9.) Basalt dikes intruded Lower Proterozoic rocks as well as Archean rocks. The barren basalt dike west of the main ore zone may be this age.

10.) Ajibik Quartzite, presently exposed as a fault bounded wedge south of the Ropes deposit, was downdropped along a steep listric normal fault along its north side. This listric normal fault was second order to regional listric normal faults which controlled the steep north sides of the Dead River and Clark Creek basins, and the Marquette trough, coincident with extension of these Early Proterozoic basins. Major shear zones, probably originally formed during the late Archean, such as the Dead River and the Carp River Falls shear zones, were reactivated in some cases and may have acted as controlling faults for both extension and later closure of the Early Proterozoic basins.

11.) Steep north northeast striking brittle faults with maximum dextral offset of tens of meters in map view cut the inlier of Ajibik Quartzite south of the Ropes deposit, the contact of the serpentinitic peridotite with the volcanic rocks of the Bjork - Lundeen block, and the main ore zone of the Ropes deposit. Their orientation is consistent with an origin as strike slip faults developed during north northeast - south southwest oriented compression during the Penokean Orogeny. This compression was oblique to some contacts between Archean and Proterozoic rocks, and caused drag folds along the south margin of the Proterozoic Dead River basin along the north side of the Archean Kitchi block, in the Zhulkie Creek area northeast of the Ropes deposit.

12.) North trending, followed by east trending, Keweenawan diabase dikes intruded the area, although they are sparse to absent in the vicinity of the Ropes deposit.

CHAPTER 7 CONCLUSIONS

7.1 Ropes Deposit

The four major rock types in or immediately bounding the Ropes deposit are: 1.) Fine grained quartz - sericite - chlorite rock encloses ore and is a narrow tabular trend which strikes 070° overall, but 080° where it hosts the Ropes deposit, and dips steeply south. This rock type is bounded to the north and south by, 2.) fine grained, carbonate - quartz - chlorite rock which is massive to compositionally layered on a scale of several millimeters. It and the quartz - sericite - chlorite rock are locally complexly interlayered, particularly in the west part of the deposit and have generally sharp contacts. Carbonate - quartz - chlorite rock is flanked successively, on both the north and south sides by, 3.) fine grained, massive to moderately foliated, carbonate - talc rock , and 4.) fine grained, serpentinitic peridotite which commonly has relict cumulate texture after original olivine and lesser pyroxene. Contacts between carbonate - quartz - chlorite rock and carbonate -

talc rock, and between carbonate - talc rock and serpentinitic peridotite are generally gradational over one to several meters.

7.1.1 Interpretation of Rock Types

1.) Quartz - sericite - chlorite rock which hosts the Ropes gold deposit has relict textures after feldspar phenocrysts and lithic fragments, and less mobile trace element abundances which indicate its protolith was mostly dacite tuff, with subordinate basalt. This is consistent with the overall decrease in the proportion of basalt in the volcanic rocks, as the deposit is approached from the west. Quartz - sericite - chlorite rock grades into relatively unaltered tuff several hundred meters west of the deposit, with decreasing sericite content in feldspar in the phenocrysts and matrix of the tuff.

2.) Carbonate - quartz - chlorite rock which bounds and is locally interlayered with the quartz - sericite - chlorite rock has abundances of rare earth and less mobile trace elements, as well as gradational contacts with carbonate - talc rock and serpentinitic peridotite, which indicate that its protolith was peridotite.

3.) Carbonate - talc rock has similar abundances of less mobile trace elements and Cr compared to serpentinitic peridotite, as well as local relict cumulate textures, which indicate that it is carbonate - talc altered serpentinitic peridotite.

4.) Serpentinitic peridotite has relict 1 to 3 mm cumulate textures after olivine and subordinate pyroxene, pseudomorphed by serpentine. It is probably a sill complex, based on its cumulate texture and its interlayered contacts with, and inclusions of, adjacent volcanic rocks. There are local minor outlying sills. Overall, the peridotite may occupy a northeast trending structurally favorable zone, coincident with a major interlayered transition between basalt and dacite tuff in the southwest part of the greenstone belt.

7.1.2 Distribution of Ore and Ore Minerals

1.) The Ropes main ore zone is steeply dipping, 335 m in maximum strike length, 12 m in average thickness and 600 m in known down - dip extent. Ninety five percent of the ore is dispersed pyrite with gold in quartz - sericite - chlorite rock, whereas five percent of the ore is in layered auriferous quartz veins.

2.) The Ropes main ore zone is divided longitudinally into three subtypes of ore with approximately 3 to 8 percent dispersed pyrite, which have gradational relationships with each other, based on proportions of quartz, sericite, chlorite, and pyrite in the ore.

3.) Most gold is 1 to 10 micron grains included within or attached to sub 100 micron pyrite. This pyrite is dispersed throughout the mass of the quartz - sericite - chlorite rock, on foliations, and within and along the margins of millimeter - thick quartz veinlets.

4.) Pyrite is approximately 97% of the metallic minerals, followed by 1% chalcopyrite. Argentiferous galena, argentiferous tetrahedrite, tetrahedrite and sphalerite are present in trace amounts. Silver is in galena, tetrahedrite, as native silver, and as electrum with gold.

5.) Au/Ag for the Ropes deposit is 0.65, which is very low compared to an average ratio of approximately 4.2 for Precambrian lode gold deposits.

7.1.3 Structure

1.) The Ropes deposit is hosted in a dilational bend in a north side down, oblique dextral slip, brittle - ductile shear zone which ranges in attitude from high angle reverse to vertical. Slip was along a line plunging approximately 60° east. The deposit is localized in an 080° striking part of a trend of quartz - sericite - chlorite rock which strikes 070° overall, bound north and south by rocks derived from peridotite. Contacts between quartz - sericite - chlorite rock and rocks derived from a peridotite protolith were planes of weakness which facilitated shearing. Local dilatancy caused by oblique dextral shear facilitated access by gold bearing fluids and resulted in formation of major zones of gold concentration with dispersed pyrite. Parts of these zones of gold concentration are oriented in right stepping en echelon low angle sigmoidal fashion. Their central parts strike 065° compared with the 080° strike of the contacts of the trend of quartz - sericite - chlorite rock with the enclosing rocks.

2.) Quartz - sericite - chlorite rock in the deposit dips vertically at depth but steeply south near surface, and is narrower updip as well as along strike to the east. This provided a constriction which may have helped to focus ascending hydrothermal fluids and localize ore.

3.) Foliation is interpreted as tectonic schistosity, or S fabric, because it is defined by secondary phyllosilicate minerals which cut, deform, and locally displace relict primary magmatic features such as domains of former feldspar phenocrysts. Preservation of primary textures in parts of the quartz - sericite - chlorite rock indicate deformation was concentrated along discrete zones in this rock type. Well foliated carbonate - quartz - chlorite rock and well foliated parts of the carbonate - talc rock do not have primary magmatic textures, but do have local S - C tectonic fabrics.

4.) Structures formed directly by ore include: 1.) right stepping en echelon, low angle sigmoidal zones of greater gold concentration within the dominant type of ore characterized by dispersed pyrite, and 2.) layered quartz veins with schistose inclusions of quartz - sericite - chlorite rock, which have a similar geometry and orientation, and plunge parallel to the S /C intersection. Zones of greater gold concentration with dispersed pyrite in quartz - sericite - chlorite rock are not symmetrically zoned about the veins, but are locally along the eastward continuation of the same 065° trend from the veins.

5.) Auriferous quartz veins and en echelon groups of these quartz veins separated by foliated quartz - sericite - chlorite rock are concentrated at the south side of the deposit, strike in right stepping en echelon fashion at approximately 15 degrees to the overall contacts between rock types on the north and south of the deposit, dip vertically to steeply south, have slight sigmoidal geometry, plunge steeply west and are progressively further east at deeper levels. Their orientation, distribution, internally layered structure, and the texture of the quartz are consistent with an origin as oblique shear veins. These veins were the target of original mining in the 1880's and 1890's and constitute approximately 5% of the ore.

6.) Continued north side down dextral oblique slip resulted in a shallowly south dipping fault in the orientation of a Riedel shear, possibly formed as the hydrothermal system cooled, below the 900 mine level.

7.) Mappable zones of gold concentration with dispersed pyrite, auriferous quartz tetrahedrite veins, and alignment of sericite, chlorite, talc, and locally fine grained auriferous pyrite follow schistosity, therefore gold deposition and hydrothermal alteration were contemporaneous with simple shear deformation.

7.1.4 Controls by Composition of Rocks and Fluids

1.) Carbonatization of serpentinitic peridotite provided a sink for CO_2, and sericite alteration of dacite tuff provided a sink for K, which were probably contained in the gold bearing hydrothermal fluid.

2.) The limited range of compositions of the major rock forming minerals, and simple mineral assemblages on the scale of the deposit, as well as the limited range of C and O isotopic values in ore, suggest an advanced state of mineralogic and isotopic homogeneity. This may have been promoted by extensive fluid flow, indicating a high water to rock ratio. This is consistent with the structural style of the deposit, because a dilational bend would promote, rather than restrict, fluid flow during simple shear.

7.1.5 Exploration Targets

1.) A number of trends of carbonate - talc altered rock, some associated with apparent dextral offset of the margin of the Deer Lake Peridotite, are known from direct observation or inferred from linear trends of lower total magnetic field within and at the margins of the DLP. These may host altered volcanic rock in settings analogous to the Ropes deposit. Presence of ferroan dolomite as one of the major carbonate minerals in this setting would enhance the prospectiveness of a target area, because this carbonate is common peripheral to Ropes, with other concentrations of gold in the Marquette greenstone belt, and with many other gold deposits in the Superior province.

2.) Ag and Sb have a positive correlation with gold abundance at Ropes and may serve as pathfinder elements.

3.) Known and inferred more major shear zones which bound blocks of the Marquette greenstone belt are parallel to the northeast, east, and east southeast strikes of many of the known gold occurrences within the Bjork - Lundeen and Silver Mine Lakes blocks These more major shear zones and their possible splays, although nearly always poorly exposed, must be systematically explored for gold concentrations.

7.2 Regional Scale and Greenstone Belt Scale Considerations

1.) The Marquette greenstone belt is 2.7 Ga late Archean volcanic rocks, dominantly tholeiitic basalt with lesser calc - alkalic intermediate to felsic rocks. It is interpreted as mostly a mafic ocean plain sequence, based on the presence of abundant pillowed basalt and minor deep water graphitic argillite. Subordinate parts of the belt may be arc type volcanic rocks, with thick dacite tuffs and tuff breccias of the Kitchi block representing a constructional volcanic edifice. The age of the greenstone belt, and its physical geology, chemistry of rocks, and geographic position are consistent with a position in the southern part of the Wawa subprovince of the Superior province of the Canadian shield.

2.) The Marquette greenstone belt is five, or possibly six blocks, each generally with an internally consistent younging direction and sequence of rock types. The blocks are bound by shear zones characterized by phyllonitic rocks, commonly accompanied by zones of secondary carbonate and sericite.

3.) There are structures with fabrics indicative of simple shear in the Ropes deposit, Bjork - Lundeen block, Marquette greenstone belt as a whole, and Great Lakes tectonic zone south of the greenstone belt. Their orientation is compatible with northwest - southeast directed compression in the Late Archean, consistent with observations by other workers in Superior province greenstone belts of Minnesota and Ontario.

4.) The largest and most abundant gold occurrences in the Marquette greenstone belt are concentrated in the Bjork - Lundeen block and in two parts of the Silver Mine Lakes block, near shear zones which bound the blocks.

5.) Most gold occurrences in the Marquette greenstone belt are at or near contacts between contrasting rock types and have evidence for simple shear, suggesting ductility contrasts between rock types were important in localizing gold. Occurrences such as the Bjork - Lundeen and Michigan mine gold bearing quartz vein systems, which are entirely within mafic vo' nic rocks, generally have little or no alteration of wall rocks.

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ROPES PYRITIC GOLD DEPOSIT IN A DILATIONAL BEND, MARQUETTE GREENSTONE BELT, MICHIGAN

Volume II

by

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Jensen Cation Plot

The Jensen Cation plot (Jensen, 1976) defines komatiitic, tholeiitic, and calc - alkalic suites of volcanic rocks by relating cation percentages of Al_2O_3; $FeO + Fe_2O_3 + TiO_2$; and MgO on a ternary diagram. These cations are relatively stable under deuteric and metamorphic alteration processes compared to K, Na, Ca, and Si.

Whole Rock Analyses

Whole rock analyses for major and trace elements on 46 samples from the Ropes deposit were performed by X - ray Assay Laboratory, Don Mills, Ontario, using a Phillips PW 1600 simultaneous X - ray spectrometer. Sample pulps were prepared using an agate mortar. Detection limits are 0.01 wt.% for major elements; 10 ppm for Cr, Rb, Sr, Y, Zr, Nb, and Ge, and 1 ppm for Ga. H_2O and CO_2 were by wet chemical methods, with a 0.1 wt.% detection limit. Acid extractable Ni and V were by DCP emission spectrometry, with detection limits of 1 and 2 ppm respectively. Rare earth and actinide elements analyses on 9 samples were done by Neutron Activation Services, Hamilton, Ontario using induced neutron activation methods. Detection limits in ppm were: Sc (0.1), La (0.1), Ce (1), Nd (3), Sm (0.01), Eu (0.05), Tb (0.1), Yb (0.05), and Lu (0.01). Au was determined by Hunter Mining Laboratory, Sparks, Nevada, by fire assay with atomic absorption spectrometry finish using half assay-ton charges, with a 34 ppb detection limit. 21 element ICP analyses, along with Ag, As, Sb, Bi, and Hg by atomic absorption spectrometry and Au by fire assay with atomic absorption spectrometry finish, for 38 rock samples, was done by Chemex Labs, Vancouver, BC. A correlation matrix was calculated using Statsview for the Apple Macintosh computer.

Distribution of Less Mobile Trace Elements

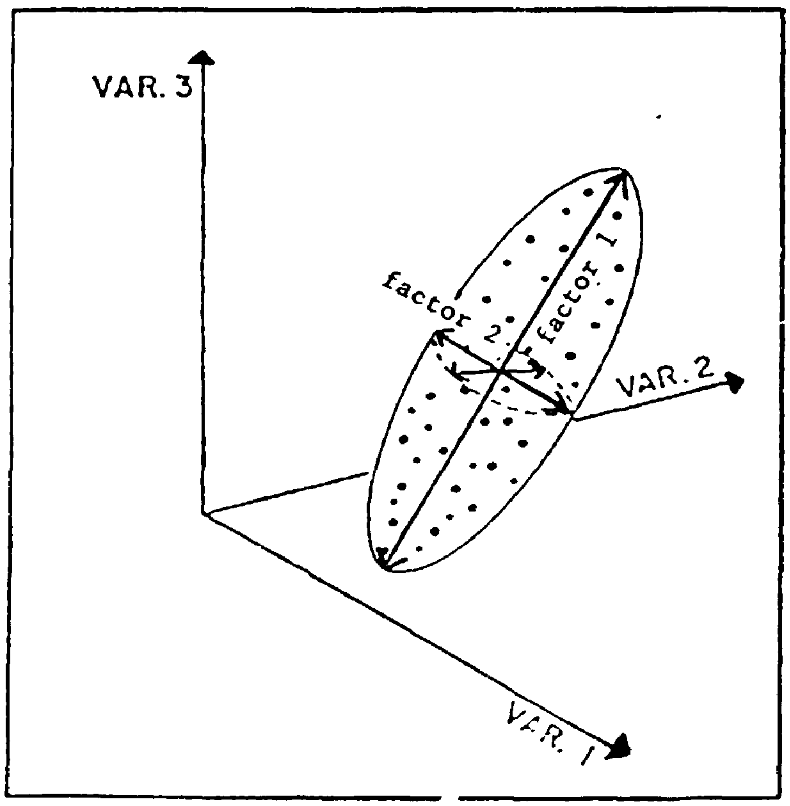
Less mobile trace element plots are most commonly used for discriminating among different magma series and their differentiation products in fresh volcanic rocks (Winchester and Floyd, 1977; Floyd and Winchester, 1975). However, some workers have used rock classification systems based on less mobile trace element plots for a range of altered volcanic rocks of Archean age (Floyd and Winchester, 1978; Jahn and others, 1974; Jahn and Sun, 1979), as well as for ultramafic rocks in particular (Nesbitt and Sun, 1976). Some examples of probable mobility of generally immobile trace elements for certain carbonate dominated systems have been cited (Hynes, 1980; Ludden and others, 1984). Elements such as Ti, Zr, Ce, and Ga are all high field strength elements with high charge to radius ratios, and as a result are not usually easily transported in aqueous fluids. Therefore, abundances and ratios of these and similar less mobile elements in altered volcanic rocks can commonly be used to ascertain the nature of the protolith (Pearce and Norry, 1979).

Principal Components Factor Analysis

Principal components factor analysis is a mathematical method for identifying the minimum number of influences, or factors, necessary to account for the maximum observed variability in a data set. The method also indicates the extent to which each factor accounts for the variance observed in the data. The abundance for each variable in the geochemical analysis of a given rock sample is mathematically plotted in n - dimensional space, where n is the number of variables, so that one point in that space represents the rock sample. For example, if n = 3, points representing individual samples might plot as illustrated in figure A-1. The long axis of the group of points represents Factor 1, which accounts for the largest percentage of variability within the data set. Factor 2 accounts for the next largest percentage of variability, and so forth. These factors can be emperically related, in certain cases, to various geologic processes which have affected the rocks, such as igneous differentiation or hydrothermal alteration.

In the case of samples from the Ropes deposit, principal components factor analysis defined groups of elements which vary together and which therefore might be related to the same process. Observed variations are attributed to possible geologic processes. Principal components factor analyses on major oxides only using 13 variables, and on the major oxides and trace elements using 19 variables, gave very similar results; therefore, only results of the more complete 19 variable example are presented in Chapter 3.3.3. A value of >0.5 or <-0.5 in a table of factor patterns (appendix C-3) means that a given variable, the row, has a relatively strong effect on the corresponding factor, the column. A positive number for a variable means that increased amounts of that element affect the corresponding factor in the positive direction; conversely, a

Figure A - 1. Schematic illustration of the concept of principal components factor analysis illustrating hypothetical variation among a group of samples plotted as points in 3 dimensional space, where each orthogonal axis represents a variable. The concept can be extended to n variables.


VAR. 3
factor 2
factor 1
VAR. 2
VAR. 1

negative number means that increased amounts of a given variable affect the corresponding factor in the negative direction. Principal components factor analysis of whole rock major and trace element abundances was completed using the SAS statistical package available on the University of Western Ontario IBM mainframe (Nie and others, 1975).

Petrographic Examination of Flotation Mill Concentrate

Two samples, 600 g and 700 g respectively, of flotation mill concentrate from the Ropes mine ore were screened into >200 mesh; 200 to 270 mesh; <270 to 325 mesh; <325 to 400 mesh; and <400 mesh fractions (Rorick, 1986) and separated into sink and float products using methylene iodide having a specific gravity of 3.33. Sink products were cast into one inch acrylite thermoplatic mounts. Briquette surfaces were ground flat and polished on a series of Pb laps using diamond powders. Polished surfaces were examined under a metallurgical ore microscope in reflected light using bright and dark field illumination and polarized light. Energy dispersive spectroscopy analyses using an electron microscope generated qualitative X - ray spectrums on Au and Ag particles (Rorick, 1986).

Mineral Analyses using Electron Microprobe

Compositions of sericite, chlorite, talc, serpentine, carbonate minerals, and chromite were determined for over 400 mineral grains by the author using a three - spectrometer MAC 400 electron microprobe with Krisel automation system (Finger and Hadidiacos, 1972). Standards used were appropriate natural minerals, and accuracy of analyses was periodically checked by analyzing a separate internal standard as an unknown. Operating conditions were 15 kV acceleration voltage and 0.03 microampere sample current. All analyses were converted to mineral compositions with an on-line PDP-11/05 computer using the MAGIC IV data-reduction program, and program SUPREC written by Dr. J. Rucklidge of the University of Toronto. For all minerals analyzed, the absolute weight percent uncertainties estimated are as follows: SiO_2,+/-0.9; TiO_2,+/-0.2; Al_2O_3,+/-0.4; FeO,+/- 0.2; MgO, +/- 0.2; CaO, +/-0.2; Na_2O, +/- 0.2; K_2O, +/- 0.2.

Au/Ag

Au/Ag was calculated from assay data from 78 drill core intercepts of the Ropes Main ore zone which meet minimum requirements of 2.05 g/tonne Au over a 3 m mining width (Dowis, 1984). The largest set of assays which also include Ag was for the uppermost reserve block down to the 420 level (table 3.6). Au/Ag for this block is 0.67. Overall Au/Ag, weighted by drill intercept length, for all 78 drill core intercepts is 0.65.

Overall Au/Ag, using all samples with both Au and Ag assays and with greater than 1.37 g/tonne Au and less than 27.74 g/tonne Au from 300 and 420 level drilling, RU-series drilling from underground, and RS-series drilling from surface, is 0.8 (Margeson, 1984).

Metal Distribution

Variograms are mathematical graphs, showing variance between Au concentration, on the y axis, as a function of distance between assay interval centerpoints, on the x axis. Variograms are constructed with the underlying philosophy that assay intervals nearby one another will have a relatively small average variation, those further apart will show a greater variation, and finally, beyond some critical distance, there will be no statistical connection between values.

Bideaux (1982) evaluated overall metal grade distribution in the Ropes deposit, using a total of 3091 assay intervals where Au concentration was greater than 0.034 g/tonne and less than 20.55 g/tonne and drill core intercept length was greater than 0.76 m . This was 99.2% of all assay data available at that time. Au assay data at approximately 1.52 m core interval resolution have relatively sharp contacts between higher grade intervals with greater than 3.42 g/tonne Au and lower grade intervals with less than 1.02 g/tonne Au. Because the most common assay interval for the Ropes deposit is 1.52 m, a spherical variogram at that spacing was computed (Bideaux, 1982). By spherical it is meant that all adjacent assays are considered within a sphere about any single assay. For each assay interval, all others surrounding it, regardless of direction, are compared, and the squared differences in gold values are computed. These squared differences are averaged for all assays within each distance class interval, resulting in the computed spherical variogram, showing the average grade continuity in three dimensions.

C and O Isotopic Analyses of Dolomite and Calcite

Determination of C and O isotopic abundances for calcite and dolomite is the result of a joint effort by Dr. R. Kerrich, Dan Farago, and the author. Procedures used for preparation of samples and extraction of CO_2 are from Kerrich (1981).

Fluid Inclusion Characteristics

Jim Reynolds, Fluid Inc., Denver, CO. provided an initial reconnaissance evaluation of fluid inclusions in ore samples. Thirteen doubly polished rock chip samples from the Ropes mine 650, 1020 and 1152 levels were examined. Samples which have later stage clear quartz are described below; all were from within ore zones, and some were from within zones of greater Au concentration within the ore:

RISO - 25 (650 level, 170E, south rib): light gray, microcrystalline, siliceous quartz - sericite rock with tetrahedrite, chalcopyrite and bornite; has pyrite in more chlorite - sericite rich selvages (within or near 6.8 g/tonne Au ore).

1020 level - 320 E - 2: light gray quartz vein with tetrahedrite (within >3.4 g/tonne Au ore).

1020 level - 710E - S: olive green quartz - sericite - pyrite rock with gray subrounded quartz fragments up to 0.5 cm size and discrete centimeter - spaced better foliated zones (within 3.4 g/tonne Au ore).

1020 level 180E - N: light green quartz - sericite rock with dispersed pyrite (within approx. 2.4 g/tonne Au ore).

Age Determination by K/Ar of Sericite

The isotope ^{40}K makes up about 0.01% of naturally occurring K and undergoes several kinds of radioactive decay. About 11% of ^{40}K nuclei decay to ^{40}Ar by electron capture. The decay to radiogenic ^{40}Ar is useful, since most K minerals have no original Ar. The calculated age of a mineral is the true age only if no radiogenic ^{40}Ar has escaped from the mineral since its formation, no excess ^{40}Ar was present in the mineral when it formed and none was introduced later, and no K was added or removed. Escape of Ar is hastened by high temperature, and for most minerals this temperature is on the order of several 100° C. If an episode of metamorphism has maintained temperatures high enough for all Ar to escape from a rock, the ^{40}K geochronometer will be reset and age determinations will record the time of metamorphism rather than the time of formation.

K-Ar age was determined on a sample of sericite - quartz - chlorite rock with pyrite from the Ropes main ore zone. Analysis was by Krueger Enterprises, Geochem Laboratories Division, Cambridge, Mass. A -80 to +200 mesh sericite concentrate was prepared from a crush sample. The fine grain size of the sample precluded separation of an absolutely pure sericite concentrate. All sulfide was removed using heavy liquids. The mineral concentrate was fused under vacuum, and the purified argon gas was analyzed for isotopic composition in an AEI MS 10 mass spectrometer. Potassium analyses were performed by lithium metaborate fusion and flame spectrophotometry. All analyses were performed in duplicate, and age was computed using the mean of the values.

Carbonate and Alkali Saturation Indices

Saturation indices can indicate the intensity of hydrothermal alteration. The molar ratio $CO_2/(Fe+Mg+Ca)$ indicates the degree of carbonatization. Most of the bivalent metal cations in fresh volcanic and igneous rocks are present in silicates and the molar ratio is close to zero, but as carbonatization proceeds, these cations are progressively transferred to carbonate minerals and the ratio approaches 1 (Kishida and Kerrick, 1987). For the alkali saturation index, assuming the ideal mineral composition for sericite, $KAl_3Si_3O_{10}(OH)_2$, the mole fraction K:Al is 1:3, therefore the ratio $3K/Al = 1$ represents saturation relative to sericite.

APPENDIX B: WHOLE ROCK ANALYSES FROM MARQUETTE GREENSTONE BELT

Whole rock analyses from Marquette greenstone belt listed in order by map sample number noted in column 3, this appendix and on map plate 1a.

Whole rock analyses from Marquette greenstone belt:

rock samples coded by:
Column #

1 and 2- UTM east and north coordinates

3- sample number on digitized sample map of Marquette greenstone belt (map plate 1b)

4- original sample number

5- Marquette greenstone belt geologic block (see figure 2.4):

- P = Deer Lake Peridotite
- B = Bjork - Lundeen block
- N = North block
- D = Dead River pluton
- K = Kitchi block
- G = Compeau Creek Gneiss
- MN= Mona block, Nealy Creek Member
- MS= Mona block, Sheared Rhyolite Tuff Member
- M = Mona block, Lower Member
- S = Silver Mine Lakes block

6- rock type code designation, as indicated on explanation on the following page, taken from field name or from referenced report.

7- original field name or rock name from referenced report

8 and 9- reference and year of reference

10 through end of table - whole rock analyses

Note: Rocks within the Ropes deposit, sedimentary rocks (code 4), or plutonic rocks (code 6), are not plotted on the Jensen ternary diagrams used in Chapter 2 to characterize the volcanic and subvolcanic rocks in the greenstone belt.

Rock type code designation for samples from Marquette greenstone belt; number and letter codes correspond to codes in column 6, appendix B

11. vein
    - q - quartz
    - c - carbonate

8. Keweenawan diabase dike

7. gneiss
    - f - felsic
    - m - mafic

6. intra - greenstone belt intrusive rocks
    - a. granite
    - b. granodiorite
    - c. tonalite
    - d. quartz monzonite
    - e. syenite
    - f. diorite
    - g. coarse feldspar porphyritic syenite

5. ultramafic intrusive rock
    - a. serpentinitic peridotite
        - c - carbonate rich
        - t - carbonate - talc rock
        - d - compositionally layered carbonate - quartz - chlorite rock (alteration product of serpentinitic peridotite protolith)

4. sedimentary rocks
    a. conglomerate
    b. graywacke
    c. siltstone
    d. slate
    e. volcaniclastic wacke
        f - felsic
        m - mafic
    f. carbonaceous slate
    g. quartzite
    h. dolomite and silty dolomite
    i. sandstone
    j. arkose

3. chemical sedimentary rocks
    a. iron formation
        o - oxide facies
        p - sulfide facies
        s - silicate facies
        c - carbonate facies
    b. chert
    c. chert with volcaniclastic component

2. dacite, rhyodacite and rhyolite; 1.5. andesite
    a. flow/dome
        p - porphyritic
    b. tuff
        p - porphyritic
        f - tuff breccia
        l - lapilli tuff
        m -sericite rich
        s - siliceous, commonly with abundant quartz veins
    c. hypabyssal sill/dike
        p - porphyritic

1. basalt
    a. flow
        p - pillowed
        v - variolitic
        o - ophitic

f - flow top breccia
g - glomerophyric
c - carbonate rich
m - sericite rich

b. tuff

f - tuff breccia
l - lapilli tuff
c - carbonate rich
m - sericite rich

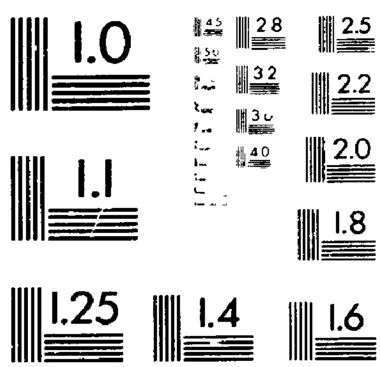
c. comagmatic gabbro intrusive, mostly sills

d. diabase dike/sill

e. layered amphibolite

s - felsic schlieren

6



Appendix B. Whole rock analyses from Marquette greenstone belt. Compiled for Callahan Mining Corp. by S. S. Schiff

EAST COOR.	NORTH COOR.	MAP SAMPLE #	ACTUAL SAMPLE #	MAP BLOCK	ROCK CODE	ROCK DESCRIPTION	REFERENCE NAME	REFERENCE YEAR	ELEMENTS SiO2	Al2O3	Fe2O3	FeO	MgO
45367.49	53019.16	001	ROPES752 XCUT	P	5a	serpentine	Bornhorst	1986	34.46	2.07	1.56	4.03	37.73
44964.09	53331.28	002	ROPES752 XCUT	P	5a	serpentine	Bornhorst	1986	42.18	0.98	1.55	8.31	36.12
56364.90	60019.22	003	P-132-67	N	2c	felsic intrusive in Lighthouse Pt. mbr.	Puffett	1974	70.80	14.60	1.40	0.92	0.98
41967.65	52232.99	004	P-1-48.6	B	2b	felsic tuff	Callahan (Pen. st.)	1986	66.89	14.51	1.78	1.57	1.95
41964.66	52236.08	005	PP-1-103	B	1a	fine grained chloritic rock	Callahan (Pen. st.)	1986	74.35	7.86	1.67	3.18	2.32
41970.76	52235.99	006	PP-1-125.5	B	1a	basalt	Callahan (Pen. st.)	1986	60.35	19.87	1.82	2.89	3.05
41967.71	52236.04	007	PP-2-281	B	2a	felsic intrusive	Callahan (Pen. st.)	1986	75.43	12.02	1.66	0.42	0.49
41967.71	52236.04	008	PP-3-52	B	1a	basalt	Callahan (Pen. st.)	1986	44.50	13.04	3.72	11.36	6.05
41961.44	52226.97	009	PP-4-251	B	2b	quartz eye tuff	Callahan (Pen. st.)	1986	70.95	14.83	1.75	1.04	1.71
41970.81	52239.04	010	PP-4-171	B	1a	basalt	Callahan (Pen. st.)	1986	48.62	12.98	2.74	10.28	4.44
41967.71	52236.04	011	PP-4-317	B	1d	mafic dike	Callahan (Pen. st.)	1986	48.62	11.43	3.42	11.44	3.54
41970.76	52235.99	012	PP-3-330	B	2b	felsic tuff	Callahan (Pen. st.)	1986	53.26	13.65	1.83	1.93	4.99
41970.76	52235.99	013	PP-4-353	B	1a	basalt	Callahan (Pen. st.)	1986	48.36	15.52	2.26	9.40	7.94
44857.47	53362.77	014	3-3-40	B	2b	dacite tuff	Brozdowski	1986	61.30	16.20	2.19	2.79	3.21
44564.22	53362.29	015	3-3-28	B	1a	basalt	Brozdowski	1986	49.70	13.70	2.59	8.83	7.52
59679.04	54595.88	016	P-212-64	D	6f	hornblende diorite	Puffett	1974	53.70	16.10	3.80	4.20	5.30
59073.83	55489.79	017	P-213-64	D	6b	granodiorite porphyry	Puffett	1974	65.30	15.20	1.00	1.60	2.50
59605.32	56464.87	018	P-214-64	D	6b	granodiorite porphyry	Puffett	1974	66.50	15.40	1.00	1.70	1.30
54843.34	55050.98	019	P-829a-65	D	6e	hornblende-biotite-syenite porphyry	Puffett	1974	57.40	16.50	2.00	2.50	3.00
52983.64	52752.73	020	P-104-65	K	6g	dacite feldspar porphyry	Puffett	1974	60.10	15.00	0.81	5.90	4.60
52378.12	52245.12	021	P-105-65	K	6g	latite feldspar porphyry	Puffett	1974	59.90	15.60	1.50	4.20	3.50
52148.18	52594.09	022	P-106-65	K	1.5a	pigeonite andesite	Puffett	1974	61.30	16.30	0.64	4.60	6.10
52104.63	52395.78	023	P-107-65	K	2bf	rhyodacite clast in agglomerate	Puffett	1974	64.80	15.60	1.50	2.40	3.00
52101.57	52392.74	024	P-107-65	K	2a	dacite	Puffett	1974	62.00	15.10	0.60	5.00	6.70
51539.25	50935.223	025	KR-3	K	2bl	lapilli tuff	Creasy	1982	62.40	16.30	2.16	2.31	2.54
51539.25	50935.223	026	KR-8	K	2bl	lapilli tuff	Creasy	1982	60.50	15.00	2.22	4.30	5.00
46500.16	52288.17	027	KR2-10	K	2b	tuff	Creasy	1982	52.70	17.30	3.19	9.37	6.01
51417.27	48232.52	028	KR2-12	K	2bl	lapilli tuff	Creasy	1982	58.90	14.90	2.11	5.31	6.02
51417.27	48232.52	029	KR2-13	K	1b	chloritic-pyritic tuff	Creasy	1982	43.40	16.10	2.71	15.02	10.10
53644.94	52133.42	030	KR3-8	K	2bl	lapilli tuff	Creasy	1982	65.10	16.10	2.09	3.27	5.15
53580.89	52118.39	031	KR3-9	K	2bs	siliceous tuff	Creasy	1982	68.70	14.70	1.93	1.58	2.73
52144.76	52511.66	032	KR[illegible]12C	K	2b	tuff	Creasy	1982	63.50	15.20	2.19	2.74	2.60
52144.76	52511.66	033	KR14-12D	K	2b	banded tuff	Creasy	1982	61.50	19.10	2.24	1.83	2.47
52144.76	52511.66	034	KR14-12S	K	2b	banded tuff- pyritic layer	Creasy	1982	59.90	16.50	2.15	4.39	3.73
52144.76	52511.66	035	KR14-12W	K	2b	banded tuff- light colored layer	Creasy	1982	64.80	19.60	2.33	0.25	1.17
44073.62	52825.82	036	KR5-2	B	2b	crystal tuff	Creasy	1982	59.10	14.30	2.26	4.84	6.36
45140.46	53244.18	037	KR5-6	B	2bl	slatey lapilli tuff	Creasy	1982	68.40	14.50	2.05	1.91	1.77
52605.00	47552.54	038	Van Hise (K)	K	2b	Kitchi schist	VanHise & Bayley	1895	70.80	14.80	1.83	-1.65	2.00
53238.61	45139.67	039	20-810	P	5a	serpentinite	Creasey	1982	34.80	0.61	0.32	3.30	33.20
49361.16	52828.26	040	Van Hise (P)	K	5a	serpentinite	VanHise & Bayley	1895	39.40	4.50	5.00	9.10	26.50
55946.93	52271.93	041	JG-26A-58	M	1ap	ellipsoidal metabasalt	Gair & Thaden	1968	48.93	14.41	4.05	8.46	6.01
53268.07	56470.23	042	JG-30-59	N	1a	fine-grained massive metabasalt	Gair & Thaden	1968	48.50	15.80	3.60	7.20	6.60
[illegible]1065.75	54698.20	043	JG-103-58	N	1e	layered amphibole schist	Gair & Thaden	1968	51.54	17.56	1.36	9.98	4.57
[illegible]3988.16	57766.20	044	JG-47-59	G	1a	felspathized greenstone	Gair & Thaden	1968	68.20	14.90	0.90	1.40	1.40
[illegible]687.98	58797.67	045	JG-63-59	G	1a	felspathized greenstone	Gair & Thaden	1968	53.60	16.90	1.40	5.50	4.80
55246.47	51934.94	046	P-126-65	M	1a	Mon. basalt	Puffett	1974	47.70	15.30	0.00	10.90	6.30
[illegible]1035.78	56828.87	047	P-66a-66	MN	4em	Nealy Creek mbr.	Puffett	1974	63.50	14.20	1.00	4.60	3.60
53021.01	55598.39	048	P-173c-65	MN	4em	Nealy Creek mbr.	Puffett	1974	64.00	15.10	0.82	4.80	3.50
56331.40	57353.70	049	P-205-66	MS	2a	Sheared Rhyolite tuff mbr.	Puffett	1974	69.30	15.50	0.89	2.10	1.40
59669.86	59921.11	050	P-149a-66	N	1e	Lighthouse Pt. mbr.	Puffett	1974	54.40	13.00	4.30	11.00	4.10
56836.24	58496.81	051	P-676a-66	N	1e	Lighthouse Pt mbr	Puffett	1974	49.70	15.80	2.30	9.60	6.60
52276.30	61964.59	052	P-37-67	N	1e	Lighthouse Pt mbr	Puffett	1974	50.50	15.40	1.90	9.50	6.30
[illegible]5698.41	59502.68	053	P-151-66	N	1e	Lighthouse Pt mbr felsic augen zone	Puffett	1974	49.10	15.60	3.20	9.20	6.10
55220.16	61510.61	054	P-125-65	N	1a	sericitic chloritic greenstone	Puffett	1974	42.10	10.90	2.10	8.40	4.60
55342.00	61507.09	055	P-126-65	N	1a	basalt	Puffett	1974	47.70	15.30	0.00	10.90	6.30
[illegible]4851.75	61557.82	056	P-127-65	N	2cp	sericitic carbonatized felsic porphyry	Puffett	1974	66.20	14.40	1.00	0.92	1.90
[illegible]2489.11	61200.42	057	P-128-65	N	4d	slate; sericitic, chloritic	Puffett	1974	58.90	15.80	0.91	7.90	5.80
52492.31	61234.00	058	P-129-65	N	4d	carbonatized-chl-qz-ser-slate	Puffett	1974	42.80	10.90	0.69	9.10	8.40
52477.65	61359.25	059	P-130-65	N	2b	strongly sheared felsic tuff	Puffett	1974	62.70	13.90	1.90	4.20	2.70
2885.73	60661.50	060	P-131-65	S	2b	sheared felsic tuff	Puffett	1974	62.80	14.20	1.00	4.70	2.90
[illegible]3203.08	61036.38	061	3-3-46	S	1a	basalt	Gleason	1986	51.80	15.70	2.90	8.46	6.19
[illegible]5969.47	61168.66	062	3-3-51	S	1a	basalt	Gleason	1986	51.40	14.60	2.35	8.32	6.26
[illegible]5970.67	61966.06	063	3-3-53	S	1a	basalt	Gleason	1986	49.10	16.70	2.53	10.05	5.54
46967.59	61963.03	064	3-3-54	S	1e	fsp-qz-chl-amphibole rk	Gleason	1986	62.70	14.50	2.09	3.71	5.68
43022.31	62767.61	065	3-3-60	S	2bl	dacite lapilli tuff	Gleason	1986	69.80	15.30	1.84	0.76	1.63
[illegible]2786.53	63371.56	066	6-3-2	S	2bf	felsic fragmental rk	Gleason	1986	69.90	15.10	1.74	0.31	1.80
42885.77	64589.34	067	6-3-7	S	6f	diorite or monzodiorite intrusive	Gleason	1986	57.80	15.40	2.14	4.02	5.26
42897.70	64980.29	068	6-3-8	S	6f	amphibole-fsp-diorite	Gleason	1986	59.40	17.60	2.16	1.91	4.52
49977.20	66895.08	069	6-3-9	N	1a	basalt	Gleason	1986	50.10	14.60	2.58	10.73	5.73
44428.48	67789.55	070	6-3-11	N	1e	biotite-amphibole-qz-fsp rock	Gleason	1986	61.00	16.30	2.01	2.56	3.03
39105.49	68429.04	071	5-3-9	S	1e	amphibole-fsp intrusive rk	Gleason	1986	57.50	17.60	2.19	2.89	3.38
[illegible]9105.49	68429.04	072	5-3-10	S	1e	med grnd qz amphibolite rk	Gleason	1986	63.20	17.50	2.04	0.66	1.41
[illegible]989[illegible].72	65242.87	073	5-3-11	S	2cp	fsp porphyry	Gleason	1986	80.00	7.29	1.70	1.38	3.28
36752.50	68457.71	074	5-3-14	S	1a	basalt	Gleason	1986	44.50	7.11	1.91	7.73	23.20
36752.50	68457.71	075	5-3-15	S	1a	basalt or ultramafic rk	Gleason	1986	39.70	5.12	1.74	7.24	29.70
36752.50	68457.71	076	5-3-16	S	5at	talc tremolite rk	Gleason	1986	47.10	6.35	1.80	6.99	22.30
32558.49	68272.90	077	6-3-20	N	6e	syenite monzonite dike	Gleason	1986	67.50	14.50	1.81	1.25	1.24

EAST COOR. | NORTH COOR. | MAP SAMPLE # | ACTUAL SAMPLE # | MAP BLOCK | ROCK CODE | ROCK DESCRIPTION | REFERENCE NAME | REFERENCE YEAR | ELEMENTS

hiff and R. A. Brozdowski, data entry by S. S. Schiff

MgO	CaO	Na2O	K2O	TiO2	P2O5	MnO	LOI	H2O-	H2O+	CO2	SUM	Cr	Rb	Sr	Y	Zr	Nb	Ba	Au (ppb)	Ga	Ni	Sc	V	Ce	Zr
37.73	0.35	0.04	-0.01	0.06	0.01				6.50	1.22	98.03	2160				13					2920	6	70		1.
36.12	1.48	0.03	-0.01	0.05	0.02				6.20	2.15	99.07	4670				7					2240	7	52		
0.95	1.30	4.40	3.40	0.29	0.18	0.16		0.04	1.20	0.22	99.89	5		20		10		70		10	<.003	3	20		
1.95	0.78	4.38	2.99	0.28	0.10	-0.01	2.50				97.73	205		83				370			11		18		
2.32	2.06	3.31	0.44	0.17	0.02	0.01	4.46				99.85	375		26				35			40		18		
3.05	0.66	8.11	1.99	0.32	0.04	-0.01	2.97				102.07	91		85				200			6		41		
0.49	1.94	7.31	0.26	0.16	-0.01	-0.01	2.06				101.75	235		107				60			4		5		
6.05	3.37	0.10	3.24	2.22	0.45	0.15	7.60				95.80	82		20				775			24		300		
1.71	1.20	2.67	3.86	0.25	-0.01	-0.01	3.08				101.34	160		74				720			5		14		
4.44	13.42	1.97	1.19	1.24	0.23	0.15	4.58				101.84	185		183				165			48		240		
3.54	7.65	2.15	1.97	1.92	0.34	0.18	6.88				99.54	57		184				415			22		325		
4.99	7.99	6.80	0.83	0.33	-0.01	0.20	9.16				100.97	53		103				55			5		35		
7.94	3.19	4.84	0.33	0.76	-0.01	0.10	6.85				99.55	145		86				50			60		182		13
3.21	2.37	6.19	1.42	0.69	0.19	0.06	3.16				99.79	100	30	220	30	130	10		6						5
7.52	8.76	3.10	0.98	1.09	0.09	0.22	1.85				98.43	300	-10	110	10	50	20		2						30
5.30	5.70	4.40	3.50	0.75	0.63	0.14		0.10	1.40	0.20	99.92	205		1500	50	300	N	1000		200	100	20	150	500	15
2.50	1.80	3.60	5.10	0.43	0.41	0.06		0.06	1.20	1.80	100.06	48		300	10	150	N	700		15	70	7	50	N	30
1.30	1.80	4.20	4.90	0.35	0.41	0.05		0.04	1.60	0.82	100.07	48		300	10	300	100	1000		15	70	7	50	100	20
3.00	4.30	5.70	3.70	0.40	0.36	0.06		0.02	1.40	2.60	99.94	103		1000	10	200	5	1500		10	50	10	100	200	20
4.60	3.40	4.00	0.43	0.78	0.28	0.23		0.08	3.20	0.49	99.30	137		300	20	200		300		20	70	15	100	100	15
3.50	2.60	3.20	3.80	0.58	0.22	0.07		0.14	2.10	2.60	100.01	103		100	15	150		1500		20	50	10	100	70	15
6.10	0.38	4.70	1.30	0.64	0.18	0.11		0.14	3.50	-0.05	99.89	137		70	15	150		70		20	50	10	100	N	15
3.00	1.40	4.60	3.00	0.66	0.14	0.07		0.16	1.70	1.00	100.03	103		100	15	15[illegible]		700		20	50	20	100	N	15
6.70	0.38	4.20	1.20	0.60	0.18	0.07		0.16	3.70	-0.05	99.89	103		50	15	150		100		20	70	15	100	N	16
2.54	4.00	6.57	0.54	0.66	0.18	0.08	3.39				101.13					160									17
5.00	3.27	2.77	2.21	0.72	0.23	0.09	3.31				99.62					170									11
6.01	0.51	4.53	0.68	1.69	0.16	0.11	3.70				99.95					110									13
6.02	1.84	2.04	2.51	0.61	0.17	0.[illegible]	5.47				100.02					130									6
10.10	0.28	0.83	0.94	1.21	0.10	0.1[illegible]	6.39				97.26					60									14
5.15	0.26	0.27	3.02	0.59	0.17	0.02	4.00				100.04					140									14
2.73	0.89	6.32	0.67	0.43	0.13	0.03	2.54				100.65					140									16
2.60	3.13	6.13	0.99	0.69	0.19	0.05	3.08				100.49					160									130
2.47	1.73	2.55	5.18	0.74	0.19	0.03	3.16				100.72					130									130
3.73	2.92	0.94	4.56	0.65	0.23	0.07	4.23				100.27					130									190
1.17	0.93	0.54	6.94	0.83	0.19	0.00	2.76				100.34					190									.40
6.36	4.92	2.19	2.11	0.76	0.21	0.10	2.93				100.08					140									130
1.77	3.53	4.77	1.45	0.55	0.15	0.06	1.54				100.68					130									
2.00	0.36	0.47	3.50	0.33	0.26						92.70														
33.20	6.30	0.01	-0.01	0.06	-0.02	0.10				7.00	85.70														
26.50	3.70	0.50	0.26	0.66	0.17	0.12				1.23	91.14	4651													
6.01	10.63	2.46	0.33	1.04	0.08	0.21		0.10	2.78	0.30	99.79														
6.60	10.60	2.50	1.20	0.74	0.06	0.22				0.18	97.20														
4.57	7.26	2.71	0.32	0.89	0.07	0.26		0.14	2.75	0.49	99.90														
1.40	2.30	4.40	3.9[illegible]	0.30	0.15	0.08				1.00	98.93														
4.80	3.70	3.90	3.50	0.97	0.52	0.14				1.80	96.73														15
6.30	6.10	0.10	1.60	0.88	0.03	0.19		0.05	5.40	4.80	99.38	137		7	15	15	N	200		15	70	20	150	N	150
3.60	2.10	3.10	2.40	0.56	0.14	0.06		0.02	2.90	1.40	99.88	205		500	10	150	50	1500		10	100	15	150	100	150
3.50	2.20	3.00	2.20	0.62	0.20	0.04		0.00	2.80	0.18	99.46	137		500	10	150	5	1000		10	100	15	200	N	70
1.40	0.40	0.60	6.10	0.33	0.09	0.13		0.13	2.50	0.06	99.53	103		100	10	70	N	500		20	100	10	50	N	30
4.10	6.80	1.40	0.77	1.10	0.09	0.07		0.00	2.20	0.05	99.26	0		100	15	30	N	150		10	30	50	300	N	20
6.60	7.00	3.70	0.70	0.77	0.06	0.02		0.00	2.70	0.31	99.26	342		200	10	20	N	150		10	300	50	300	N	20
6.30	9.90	2.30	0.48	0.81	0.07	0.23		0.03	1.30	0.46	99.18	103		150	20	20	N	100		15	70	30	150	N	20
6.10	9.40	3.20	0.50	0.89	0.07	0.10		0.00	1.90	0.19	99.45	103		150	10	20	N	100		10	50	30	200	N	15
4.60	10.60	0.26	1.70	0.88	0.05	0.28		0.18	3.20	13.90	99.15	103		5	30	15		100		10	50	20	150		15
6.30	6.10	0.10	1.60	0.88	0.03	0.19		0.08	5.40	4.80	99.38	137		7	20	15		200		15	70	20	150		100
1.90	3.30	2.30	3.20	0.53	0.11	0.10		0.14	1.40	4.40	99.90	34		70	15	100		300		10	N	10	70		100
5.80	0.63	0.76	2.00	1.20	0.00	0.10		0.17	4.70	0.28	99.15	48		7	30	100		200		15	70	50	200		70
8.40	8.50	0.19	1.30	0.91	0.13	0.38		0.11	3.50	13.00	99.91	48		20	20	70		150		10	50	20	150		100
2.70	2.80	0.59	2.80	0.52	0.10	0.16		0.15	2.70	3.90	99.12	103		100	15	100		300		10	100	10	100		70
2.90	3.50	0.55	2.40	0.50	0.16	0.13		0.08	2.30	4.80	100.02	137		70	10	70		300		10	70	10	100		60
6.19	3.77	3.06	1.61	1.40	0.12	0.15	3.85				99.01	250	20	90	-10	60	10	330	9						20
6.26	3.46	2.75	1.24	0.85	0.07	0.14	7.16				98.60	270	30	20	10	20	20	180	22						50
5.54	7.51	1.30	2.41	1.03	0.08	0.17	2.08				98.50	260	80	150	20	50	30	460	23						160
5.68	1.26	4.91	0.54	0.59	0.18	0.07	3.23				99.46	150	30	120	20	160	10	210	14						100
1.63	0.96	5.64	1.73	0.34	0.10	0.03	2.00				100.13	90	40	450	10	100	10	510	20						80
1.80	1.13	3.22	3.27	0.24	0.08	0.0[illegible]	3.23				100.06	80	90	100	10	80	20	670	2						120
5.26	4.77	4.54	2.67	0.64	0.26	0.10	1.93				99.53	190	80	640	10	120	20	1030	5						.30
4.52	1.67	4.43	3.78	0.66	0.38	0.05	3.08				99.64	100	60	680	30	130	10	1390	5						40
5.73	9.50	2.13	0.93	1.08	0.09	0.23	1.16				98.86	50	40	90	20	40	30	170	36						120
3.03	4.54	5.09	2.61	0.51	0.23	0.07	1.23				99.68	80	80	860	20	120	10	1230	3						250
3.38	2.62	5.60	2.88	0.69	0.35	0.05	4.08				99.83	110	70	630	10	250	30	1330	-2						200
1.41	1.54	5.46	4.70	0.54	0.27	0.04	2.39				99.75	130	100	420	-10	200	20	1420	6						30
3.28	0.25	1.39	1.40	0.20	0.08	0.05	2.62				99.64	190	30	50	-10	30	10	830	7						-10
23.20	7.06	0.07	0.01	0.41	0.04	0.16	6.16				98.36	2531	10	-10	10	-10	10	90	-2						-10
29.70	3.97	0.05	0.02	0.24	0.03	0.15	9.70				97.66	3215	-10	30	-10	-10	20	90	-2						-10
22.30	7.64	0.10	0.01	0.30	0.04	0.15	5.16				97.94	1915	10	-10	20	-10	10	50	-2						40
1.24	4.71	5.17	1.97	0.3[illegible]	0.04	0.06	1.16				99.72	137	80	120	20	40	20	110	-2						

Zr	Nb	Ba	Au (ppb)	Ga	Ni	Sc	V	Ce	Ge	La	Nd	Sm	Eu	Tb	Yb	Lu	Mo
13					2920	6	70										
7					2240	7	52										
10		70		10	<.003	3	20										
		370			11		18										
		35			40		18										
		200			6		41										
		60			4		5										
		775			24		300										
		720			5		14										
		165			48		240										
		415			22		325										
		55			5		35										
		50			60		182										
130	10		6														
50	20		2														
300	N	1000		200	100	20	150	500		200							
150	N	700		15	70	7	50	N		N							
300	100	1000		15	70	7	50	100		100							
200	5	1500		10	50	10	100	200		150							
200		300		20	70	15	100	100		50							
150		1500		20	50	10	100	70		30							
150		70		20	50	10	100	N		N							
150		700		20	50	20	100	N		N							
150		100		20	70	15	100	N		N							
160																	
170																	
110																	
130																	
60																	
140																	
140																	
160																	
130																	
130																	
130																	
140																	
130																	
15	N	200		15	70	20	150	N		N							
150	50	1500		10	100	15	150	100		70							
150	5	1000		10	100	15	200	N		30							
70	N	500		20	100	10	50	N		N							
30	N	150		10	30	50	300	N		N							
20	N	150		10	300	50	300	N		N							
20	N	100		15	70	30	150	N		N							
20	N	100		10	50	30	200	N		N							
15		100		10	50	20	150										
15		200		15	70	20	150										
100		300		10	N	10	70										
100		200		15	70	50	200										
70		150		10	50	20	150										
100		300		10	100	10	100										
70		300		10	70	10	100										
60	10	330	9														
20	20	180	22														
50	[illegible]	460	23														
160	10	210	14														
100	10	510	20														
80	20	670	2														
120	20	1030	5														
130	10	1390	5														
40	30	170	36														
120	10	1230	3														
250	30	1330	-2														
200	20	1420	6														
30	10	830	7														
-10	10	90	-2														
-10	20	90	-2														
-10	10	50	-2														
40	20	110	-2														

Nb	Ba	Au (ppb)	Ga	Ni	Sc	V	Ce	Ge	La	Nd	Sm	Eu	Tb	Yb	Lu	Mo

EAST COOR.	NORTH COOR.	MAP SAMPLE #	ACTUAL SAMPLE #	MAP BLOCK	ROCK CODE	ROCK DESCRIPTION	REFERENCE NAME	REFERENCE YEAR	SiO2	Al2O3	Fe2O3	FeO	MgO
50207.84	61888.74	078	3-3-63	S	5at	serp-talc-chl-trem rk w/ amphibole porphbl	Gleason	1986	45.20	7.34	1.89	9.73	19.9
49766.30	56038.80	079	3-3-69	MN	2cp	fsp porphyritic felsite flow (dike?)	Gleason	1986	62.40	16.70	2.06	2.32	2.8
49786.75	55937.80	080	3-3-74	MN	1e	qz-amphibole-fsp rk	Gleason	1986	52.50	16.40	2.14	6.63	9.8
46599.63	52476.72	081	3-3-81	K	1ap	pillowed basalt	Gleason	1986	44.90	12.20	2.28	12.35	9.8
49693.52	67438.64	082	10B11	N	1a	basalt	Johnson	1987	48.47	12.66	4.08	7.77	6.6
49744.91	66361.47	083	10D4	N	1a	basalt	Johnson	1987	48.11	11.57	6.02	7.97	9.6
50259.26	65128.36	084	14E6	N	1a	basalt	Johnson	1987	48.37	13.09	3.21	7.33	8.7
52156.14	64603.91	085	24E24	N	1a	basalt	Johnson	1987	45.98	12.10	4.93	10.13	5.8
49669.81	66214.10	086	15A4	N	1a	foliated basalt	Johnson	1987	39.34	13.00	6.30	12.37	12.1
52078.15	64010.88	087	24E13	N	1a	foliated basalt	Johnson	1987	42.55	11.97	4.34	10.14	10.1
52631.38	63498.76	088	24H1	N	1ac	cb. altered basalt	Johnson	1987	40.48	14.08	9.14	12.17	9.0
52652.45	63398.36	089	24H4	N	1ac	cb. altered basalt	Johnson	1987	45.54	11.59	3.93	7.61	9.0
43294.34	63119.62	090	25AA	S	1ac	cb. altered basalt	Johnson	1987	48.39	13.77	4.92	9.30	9.0
51098.12	64387.31	091	23A6C	N	1c	gabbro	Johnson	1987	45.34	13.18	2.94	9.46	9.0
50923.77	64417.38	092	23A6N	N	1c	gabbro	Johnson	1987	44.98	12.06	2.65	10.22	9.0
52955.80	64318.28	093	24K28	N	1c	gabbro	Johnson	1987	50.70	10.46	5.37	9.30	7.3
51251.57	63836.08	094	23K1	N	5b	cb. altered gabbro	Johnson	1987	54.61	8.27	6.87	5.62	5.9
51831.72	63802.57	095	241D10	N	5b	foliated gabbro	Johnson	1987	44.42	13.68	4.12	7.68	16.5
50334.49	64836.09	096	14E3	N	2a	rhyolite	Johnson	1987	69.43	14.96	1.74	0.23	0.6
50463.99	63942.62	097	23AP	N	2a	rhyolite	Johnson	1987	67.59	15.96	1.70	-0.17	0.5
51380.62	64585.95	098	23L18	N	2a	rhyolite	Johnson	1987	74.33	12.99	1.53	-1.04	0.4
52384.89	63529.97	099	2467A	N	2a	rhyolite	Johnson	1987	70.45	18.35	1.72	-0.60	1.0
44056.68	63630.07	100	24K15	N	2a	rhyolite	Johnson	1987	71.75	17.53	1.51	-0.57	0.5
49606.23	67855.41	101	10A5	N	6c	tonalite	Johnson	1987	53.27	15.19	2.13	4.51	5.8
49299.63	67851.20	102	10A9	N	6d	qz monzonite	Johnson	1987	53.95	16.45	2.86	2.34	4.8
49107.26	67839.11	103	10A10	N	6b	granodiorite	Johnson	1987	58.63	15.16	1.66	3.11	4.8
48764.58	67829.41	104	10A14	N	6b	granodiorite	Johnson	1987	57.88	13.68	1.98	1.77	2.0
49591.77	65766.61	105	15C7	N	6d	qz monzonite	Johnson	1987	59.62	16.45	2.10	0.94	3.7
50262.51	64230.84	106	23A6R	N	6b	granodiorite	Johnson	1987	62.21	18.89	1.81	0.40	1.0
52916.68	64446.25	107	24K29	N	6c	tonalite	Johnson	1987	53.10	14.51	2.21	4.09	5.2
49236.74	66979.00	108	10C7	N	6d	foliated quartz monzonite	Johnson	1987	55.15	15.70	2.24	4.27	5.6
47027.43	54159.45	108.5	3-3-88	K	1a	basalt	Callahan	1986	48.10	14.80	13.80	-2.51	6.8
41025.35	64120.37	109	SC-3-1WR	S	2cp	dacite porphyry	Norby	1988	69.40	13.10	1.84	1.16	1.0
41067.41	64204.59	110	SC-3-11WR	S	6c	tonalite porphyry	Norby	1988	71.40	15.20	1.69	-0.33	0.7
40757.75	64403.58	111	SC-3-22WR	S	6d	quartz monzonite	Norby	1988	71.80	15.10	1.73	-0.52	0.2
[illegible]271.84	6[illegible]089.15	112	SC-3-30WR	S	1b	basalt tuff	Norby	1988	49.[illegible]	12.[illegible]	3.7[illegible]	12.44	4.4
[illegible]776.93	63771.84	113	SC-3-31WR	S	6c	tonalite porphyry	Norby	1988	71.80	15.20	1.70	-0.22	0.8
4[illegible]636.51	64167.45	114	SC-3-50WR	S	1b	basalt tuff	Norby	1988	64.70	15.50	2.08	2.03	2.1
[illegible]2663.68	63730.42	115	SC-3-75WR	S	2a	dacite	Norby	1988	75.50	14.00	1.58	-0.45	0.3
[illegible]3004.63	43143.674	116	SC-3-93WR	S	1a	basalt	Norby	1988	51.90	19.40	2.93	5.60	5.8
[illegible]3186.84	63255.15	117	SC-3-101WR	S	1d	diabase	Norby	1988	50.90	17.10	2.21	7.64	6.8
[illegible]2811.03	63537.05	118	SC-3-122WR	S	6c	tonalite porphyry	Norby	1988	70.40	15.70	1.75	0.35	2.3
41512.31	64124.73	119	SC-3-146WR	S	1a	basalt	Norby	1988	51.60	15.80	2.13	7.35	4.8
4[illegible]679.44	63143.74	120	SC-3-158	S	2cp	dacite porphyry	Norby	1988	76.40	13.30	1.53	-0.56	0.6
43472.03	64636.22	121	SC-3-191	S	6c	intrusive tonalite	Norby	1988	58.20	15.10	2.18	3.49	5.2
[illegible]0735.44	53104.83	122	PH-4-209	M	1a	basalt	Carter	1986	75.70	12.40	1.68	-0.58	0.9
[illegible]0335.45	52907.88	123	PH-5-253	M	1ac	carbonatized basalt	Carter	1986	50.20	12.20	2.04	4.00	4.4
[illegible]0335.45	52907.88	124	PH-5-289	M	1ac	carbonatized basalt	Carter	1986	42.70	16.10	2.31	8.63	10.5
[illegible]0338.51	52910.92	125	PH-5-298	M	1ac	carbonatized basalt	Carter	1986	3.04	0.84	1.54	3.14	18.6
[illegible]0338.51	52910.92	126	PH-5-310	M	1ac	carbonatized basalt	Carter	1986	60.10	15.70	1.92	2.40	5.0
[illegible]0335.47	52910.93	127	PH-5-322	M	1ac	carbonatized basalt	Carter	1986	48.80	15.00	2.00	6.87	10.6
[illegible]0338.51	52910.92	128	PH-5-327	M	1ac	carbonatized basalt	Carter	1986	22.80	5.41	1.58	2.43	14.7
[illegible]3645.12	53494.13	129	LM-3-104	M	11qc	ankerite qtz rock	Brozdowski	1987	15.60	1.87	1.57	5.97	13.2
[illegible]3633.25	53536.83	130	LM-3-105	M	11qc	foliated wall rk to ankerite-qtz	Brozdowski	1987	55.10	14.20	2.05	8.05	6.8
[illegible]3649.09	53616.33	131	LM-3-106	M	1c	gabbro	Brozdowski	1987	48.40	15.60	2.43	9.24	5.7
[illegible]3644.60	52205.12	132	LM-3-119	M	2a	felsite	Brozdowski	1987	62.00	14.20	2.03	4.21	2.4
[illegible]2544.38	54288.44	133	LM-3-126	M	1a	basalt	Brozdowski	1987	55.40	15.20	2.20	5.06	6.6
56836.98	52658.64	134	LM-3-134	M	11qc	ankerite-qtz rock	Brozdowski	1987	16.30	5.43	5.98	7.85	11.5
[illegible]6836.98	52658.64	135	LM-3-135	M	1as	sericite phyllite	Brozdowski	1987	56.00	15.50	2.73	7.71	6.5
[illegible]3672.27	53449.34	136	LM-3-193	M	4d	chlorite slate	Brozdowski	1987	52.70	14.50	2.14	5.68	4.6
[illegible]3395.26	52161.85	137	LM-3-191	K	4d	sericite slate	Brozdowski	1987	64.70	14.70	1.92	1.84	3.2
[illegible]0803.22	54859.54	138	LM-3-199	M	1ap	pillow basalt	Brozdowski	1987	47.70	14.10	2.62	9.34	7.1
[illegible]0521.74	54810.08	139	LM-3-200	M	1c	gabbro	Brozdowski	1987	50.00	14.20	2.39	10.63	6.0
[illegible]3972.62	54476.41	140	LM-3-213	M	1a	basalt	Brozdowski	1987	50.40	14.80	2.39	6.22	5.2
[illegible]3958.80	54259.46	141	LM-3-214	M	1c	gabbro	Brozdowski	1987	47.90	11.20	4.90	12.33	5.3
[illegible]3035.82	52005.21	142	LM-3-223	M	1c	gabbro	Brozdowski	1987	48.90	14.40	2.54	8.69	8.3
59613.39	53734.25	144	LM-3-233	M	5a	meta pyroxenite	Brozdowski	1987	50.00	14.90	2.21	7.37	9.7
[illegible]657.24	54295.50	143	LM-3-244	M	5a	serpentine bearing ultramafic rk	Brozdowski	1987	46.60	13.80	2.35	9.40	10.2
[illegible]6100.20	54093.51	145	AN-3-01	M	1a	basalt	Gleason	1986	48.00	14.80	2.31	9.17	8.9
[illegible]6102.15	54520.98	146	AN-3-05	M	1a	basalt	Gleason	1986	49.70	14.60	2.20	6.89	9.7
[illegible]5561.45	54363.51	147	AN-3-07	M	1c	gabbro	Gleason	1986	50.20	14.60	2.03	6.54	9.1
55444.82	54174.64	148	AN-3-08	M	1as	foliated basalt	Gleason	1986	47.20	13.40	2.38	8.57	9.3
[illegible]6398.27	54737.79	149	AN-3-10	MN	1c	gabbro	Gleason	1986	48.50	14.70	2.49	6.74	8.7
55366.84	54527.23	150	AN-3-11	M	1as	foliated basalt	Gleason	1986	46.90	15.70	2.46	9.21	9.8
55641.02	54944.12	151	AN-3-12	D	1c	gabbro	Gleason	1986	48.90	13.40	2.68	11.36	6.2
55666.27	54467.69	152	AN-3-13	M	1a	basalt	Gleason	1986	47.10	15.40	2.21	9.35	8.9
55658.93	54195.96	153	AN-3-15	M	1a	basalt	Gleason	1986	48.30	13.90	2.45	8.50	7.4

EAST COOR.	NORTH COOR.	MAP SAMPLE #	ACTUAL SAMPLE #	MAP BLOCK	ROCK CODE	ROCK DESCRIPTION	REFERENCE NAME	REFERENCE YEAR	SiO2	Al2O3	Fe2O3	FeO	MgO
55987.87	54179.44	154	AN-3-16	M	2cp	dacite porphyry	Gleason	1986	53.00	16.50	2.49	5.70	4.8
[illegible]	[illegible]	155	AN-3-17	M	1a	basalt	Gleason	1986	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

	MgO	CaO	Na2O	K2O	TiO2	P2O5	MnO	LOI	H2O-	H2O+	CO2	SUM	Cr	Rb	Sr	Y	Zr	Nb	Ba	Au (ppb)	Ga	Ni	Sc	V	Ce
73	19.90	7.66	0.23	0.05	0.39	0.04	0.20	5.23				97.86	1847	10	-10	10	-10	20	80	-2					
82	2.89	0.85	4.67	3.75	0.58	0.23	0.05	2.39				98.91	-68	100	430	10	170	30	960	-2					
63	9.81	0.41	3.38	0.90	0.64	0.08	0.09	5.39				98.37	479	30	80	-10	30	20	170	-2					
55	9.83	9.44	1.10	0.67	0.78	0.08	0.28	4.77				98.68	137	10	90	10	30	30	180						
77	6.68	11.10	1.25	1.26	0.92	0.10	0.19		0.05	2.57		97.10	293	24	182	17	48	5	16			171		226	
97	9.64	6.50	2.84	0.72	1.00	0.11	0.23		0.20	3.13		98.94	353	8	266	17	57	5	21			161		241	
33	8.74	9.25	1.31	2.53	0.71	0.07	0.22		0.10	3.31		98.24	400	57	181	19	41	6	26			149		178	
13	5.88	9.55	1.82	0.81	1.30	0.14	0.27		0.13	3.11		96.15	262	7	199	22	67	6	19			116		305	
57	12.18	3.28	0.97	0.53	1.21	0.09	0.22		0.10	9.50		99.09	473	12	114	16	66	7	14			206		329	
4	10.10	8.17	1.64	0.48	0.95	0.08	0.23		0.09	9.14		99.88	589	3	100	16	35	9	13			332		238	
7	9.02	1.00	2.24	0.92	1.38	0.11	0.07		0.05	6.21		96.87	524	6	46	11	55	7	15			220		359	
61	9.07	8.60	1.61	0.94	0.93	0.10	0.19		0.14	5.78		96.03	490	8	281	17	86	9	27			96		202	
80	9.04	0.32	2.52	1.64	1.02	0.07	0.07		0.05	5.16		96.27	663	28	43	13	30	8	18			227		261	
86	9.01	9.54	1.56	0.62	0.84	0.12	0.19		0.10	2.52		95.42	337	8	133	17	49	6	9			190		198	
22	9.04	9.73	1.53	0.77	0.97	0.12	0.20		0.09	3.07		95.43	293	10	133	17	49	7	13			203		228	
30	7.32	9.85	1.92	0.77	1.40	0.14	0.23		0.00	2.91		100.37	161	8	144	20	62	6	20			48		326	
62	5.92	12.80	0.26	0.43	1.07	0.24	0.13		0.14	1.92		98.28	44	1	1425	18	249	N	13			29		241	
68	16.59	2.15	0.72	1.33	1.21	0.07	0.13		0.19	7.01		99.30	471	19	44	18	40	11	37			195		300	
23	0.63	1.44	2.52	3.90	0.22	0.07	0.04		0.00	2.43		97.61	4	84	114	15	120	18	59			4		14	
17	0.51	0.43	4.90	2.96	0.20	0.06	0.02		0.05	1.44		95.65	16	57	270	8	97	8	41			5		14	
04	0.46	0.08	7.88	0.64	0.03	0.02	0.01		0.05	0.40		97.38	19	7	40	4	39	25	97			3		13	
60	1.00	0.03	0.29	5.51	0.22	0.06	0.01		0.10	2.18		99.32	11	104	19	15	112	21	97			3		15	
67	0.56	0.10	2.22	4.88	0.01	0.02	0.01		0.00	1.60		99.62	9	88	26	13	33	28	12			6		N	
51	5.88	5.43	3.51	2.28	0.62	0.22	0.13		0.05	2.19		95.41	219	61	619	17	127	N	70			102		128	
34	4.83	3.44	5.64	1.92	0.54	0.36	0.11		0.00	1.92		94.36	89	27	935	17	256	2	93			49		94	
11	4.80	2.69	3.98	3.27	0.53	0.28	0.09		0.05	3.03		97.28	80	64	597	17	195	5	142			47		90	
77	2.06	4.12	3.36	3.54	0.48	0.28	0.06		0.05	3.28		92.54	60	72	895	16	223	2	145			35		79	
94	3.75	1.45	4.08	4.62	0.60	0.31	0.05		0.05	2.55		96.57	136	90	407	16	151	7	148			98		109	
40	1.06	0.36	3.88	5.22	0.31	0.09	0.03		0.00	1.64		95.90	28	99	231	14	153	[illegible]	98			13		36	
09	5.27	3.61	2.52	2.98	0.71	0.23	0.13		0.00	5.81		95.17	301	70	322	18	135	6	97			127		140	
27	5.69	1.80	3.25	3.39	0.74	0.28	0.08		0.05	3.50		96.15	203	70	273	19	137	11	93			137		147	
51	6.84	3.21	1.60	1.50	1.29	0.11	0.10	8.16				97.10	137	80	140	20	60	-10	310						
16	1.07	1.85	4.40	1.96	0.34	0.11	0.10	3.62				98.95	-68	40	120	20	80	10	370						
33	0.74	1.07	5.50	2.39	0.19	0.06	0.04	1.85				99.50	-68	70	430	-10	90	-10	470						
52	0.25	0.31	4.23	4.70	0.23	0.08	0.02	1.08				99.01	-68	120	280	10	120	10	1046						
44	4.48	3.69	1.33	1.42	2.27	0.30	0.15	6.39				97.64	-68	30	80	30	230	70	430						
22	0.85	0.83	4.63	2.40	0.20	0.06	0.03	1.85				99.33	-68	90	300	-10	90	20	540						
03	2.15	2.72	4.50	1.70	0.58	0.21	0.07	2.62				98.86	-68	80	460	10	140	10	570						
45	0.30	0.19	2.90	3.55	0.08	0.03	0.02	1.39				99.09	-68	120	90	-10	60	20	740						
60	5.89	0.34	2.46	3.96	1.43	0.12	0.05	4.54				98.62	205	140	20	10	100	20	610						
64	6.80	2.08	1.84	2.65	0.71	0.05	0.09	6.16				98.03	342	70	40	10	10	10	360						
35	2.31	0.38	0.71	4.49	0.25	0.06	0.04	3.16				99.60	-68	170	20	-10	80	-10	570						
35	4.88	11.30	1.87	0.33	0.63	0.05	0.24	3.00				99.18	342	10	110	10	-10	10	80						
56	0.67	1.04	2.86	3.01	0.03	0.02	0.04	2.16				100.50	-68	180	20	40	30	40	210						
49	5.28	3.99	4.42	1.54	0.68	0.29	0.11	4.62				99.90	205	70	490	20	100	20	510						
58	0.96	1.48	2.12	4.01	0.18	0.06	0.02	2.16				100.19	-68	140	30	-10	140	20	600						
00	4.45	10.80	1.22	2.90	0.54	0.06	0.20	9.70				98.31	274	50	50	10	20	10	110						
63	10.50	4.64	0.08	2.57	0.81	0.07	0.16	10.20				98.77	342	110	-10	10	60	10	180						
14	18.60	29.10	0.05	0.18	0.04	0.02	0.30	41.80				98.65	-68	10	160	-10	-10	10	-10						
40	5.05	3.36	0.11	4.36	0.42	0.10	0.10	6.08				99.70	-68	170	-10	30	160	-10	240						
87	10.60	4.08	0.05	2.30	0.50	0.05	0.15	9.08				99.48	616	90	-10	10	20	10	220						
43	14.70	20.60	0.09	1.29	0.08	0.01	0.48	29.80				99.27	-68	60	40	10	-10	10	50						
97	13.20	24.30	0.02	0.26	0.07	0.02	0.60	36.00			35.70	99.48	-68	20	40	-10	-10	20	-10			53		30	
05	6.87	1.90	0.06	2.28	0.55	0.06	0.11	8.23			2.26	99.46	274	90	-10	10	70	10	170			140		180	
24	5.71	8.07	2.86	1.39	0.93	0.10	0.20	2.77			0.16	97.70	-68	60	150	20	60	10	230			54		300	
21	2.48	0.18	1.08	7.56	0.53	0.16	0.06	3.93			-0.01	98.42	-68	80	10	10	110	20	1320			8		88	
06	6.69	4.78	4.02	0.20	0.70	0.07	0.18	3.47			0.35	97.97	342	10	130	20	40	10	130			140		270	
85	11.50	17.10	-0.01	0.16	4.48	0.43	0.62	25.70			26.00	95.60	547	20	20	30	180	140	10			500		230	
71	6.53	0.31	0.04	2.03	1.23	0.10	0.06	5.16			0.25	97.40	137	70	-10	40	40	10	180			120		380	
68	4.69	12.20	2.93	0.25	0.64	0.07	0.18				1.85	95.98	342	10	140	-10	30	30	50			120		230	
84	3.23	2.09	5.63	1.01	0.42	0.12	0.07	4.31			2.56	100.09	-68	40	120	-10	160	-10	250			20		50	
34	7.13	10.20	2.49	0.32	1.12	0.09	0.20	3.00			0.55	98.31	68	10	120	20	50	20	60			90		300	
63	6.00	6.82	3.75	1.08	0.89	0.11	0.20	2.16			0.01	98.23	-68	50	130	30	60	20	260			90		300	
22	5.24	6.50	4.07	0.47	0.89	0.08	0.17	7.62			4.32	98.85	137	10	30	10	30	20	80			120		250	
33	5.38	8.99	2.10	0.74	3.40	0.35	0.26	1.16			0.03	98.71	-68	40	170	30	210	40	260			60		550	
69	8.37	7.09	3.35	0.25	1.04	0.08	0.19	3.47			0.03	98.37	205	-10	120	20	60	20	100			130		290	
37	9.75	3.36	1.68	2.39	0.71	0.08	0.22	6.47			1.04	99.14	274	30	60	20	60	10	470			70		230	
40	10.20	6.59	2.69	0.78	0.85	0.08	0.23	4.47			0.75	98.04	205	40	10	10	30	20	120			120		270	
17	8.96	8.11	2.38	0.80	0.81	0.06	0.21	2.77				98.38	205	30	90	10	30	20	150						
89	9.72	4.30	2.30	1.43	0.70	0.07	0.14	7.08				99.13	342	60	80	10	50	20	420						
54	9.19	8.35	2.63	1.41	0.53	0.06	0.16	3.00				98.70	958	60	220	20	20	-10	250						
57	9.33	6.24	1.50	0.55	0.88	0.08	0.17	8.93				99.23	274	20	50	20	40	20	100						
74	8.77	9.21	1.36	1.34	0.99	0.08	0.16	4.47				98.81	342	100	270	-10	50	20	280						
21	9.89	3.00	2.04	1.26	0.96	0.08	0.19	6.39				98.08	274	30	70	10	40	10	530						
36	6.20	8.74	1.82	1.21	1.18	0.14	0.22	2.62				98.47	68	-10	260	-10	80	30	400						
35	8.96	10.10	1.59	0.53	0.71	0.07	0.26	3.08				99.36	479	40	90	20	50	20	240						
50	7.43	10.70	2.69	0.54	0.95	0.09	0.17	2.54				98.26	342	10	110	10	70	20	120						

	MgO	CaO	Na2O	K2O	TiO2	P2O5	MnO	LOI	H2O-	H2O+	CO2	SUM	Cr	Rb	Sr	Y	Zr	Nb	Ba	Au (ppb)	Ga	Ni	Sc	V
70	4.86	3.24	3.33	3.43	0.99	0.35	0.15	4.23				98.27	-68	-10	210	10	150	10	360					

Sr	Y	Zr	Nb	Ba	Au (ppb)	Ga	Ni	Sc	V	Ce	Ge	La	Nd	Sm	Eu	Tb	Yb	Lu	Mo
-10	10	-10	20	60	-2														
430	10	170	30	960	-2														
80	-10	30	20	170	-2														
90	10	30	30	180															
182	17	48	5	16			171		226			4							
266	17	57	5	21			161		241			9							
181	19	41	6	26			149		178			2							
199	22	67	6	19			116		305			6							
114	16	66	7	14			206		329			N							
100	16	35	9	13			332		238			N							
46	11	55	7	15			220		359			N							
281	17	86	9	27			96		202			14							
43	13	30	8	18			227		261			N							
133	17	49	6	9			190		198			8							
133	17	49	7	13			203		228			6							
144	20	62	6	20			48		326			N							
1425	18	249	N	13			29		241			9							
44	18	40	11	37			195		300			N							
114	15	120	18	59			4		14			44							
270	8	97	8	41			5		14			9							
40	4	39	25	97			3		13			10							
19	15	112	21	97			3		15			47							
26	13	33	28	12			6		N			N							
619	17	127	N	70			102		128			27							
935	17	256	2	93			49		94			72							
597	17	195	5	142			47		90			90							
895	16	223	2	145			35		79			55							
407	16	151	7	148			98		109			39							
231	14	153	6	98			13		36			39							
322	18	135	6	97			127		140			51							
273	19	137	11	93			137		147			56							
140	20	60	-10	310															
120	20	80	10	370															
430	-10	90	-10	470															
280	10	120	10	1016															
80	30	230	70	430															
300	-10	90	20	540															
460	10	140	10	570															
90	-10	60	20	740															
20	10	100	20	610															
40	10	10	10	360															
20	-10	80	-10	570															
110	10	-10	10	80															
20	40	30	40	210															
490	20	100	20	510															
30	-10	140	20	600															
50	10	20	10	110															
-10	10	60	10	180															
160	-10	-10	10	-10															
-10	30	160	-10	240															
-10	10	20	10	220															
40	[illegible]	-10	10	50															
40	[illegible]	-10	20	-10			53		30										
-10	10	70	10	170			140		180										
50	20	60	10	230			54		300										
[illegible]	10	110	20	1320			8		88										
[illegible]	20	40	10	130			140		270										
[illegible]	30	180	140	10			500		230										
-10	40	40	10	180			120		380										
40	-10	30	30	50			120		230										
[illegible]	-10	160	-10	250			20		50										
[illegible]	20	50	20	60			90		300										
30	30	60	20	260			90		300										
30	10	30	20	80			120		250										
[illegible]	30	210	40	260			60		550										
20	20	60	20	100			130		290										
[illegible]	20	60	10	470			70		230										
[illegible]	10	30	20	120			120		270										
[illegible]	10	30	20	150															
[illegible]	10	50	20	420															
[illegible]	20	20	-10	250															
[illegible]	20	40	20	100															
[illegible]	-10	50	20	280															
[illegible]	10	40	10	530															
[illegible]	-10	80	30	400															
[illegible]	20	50	20	240															
[illegible]	10	70	20	120															

Sr	Y	Zr	Nb	Ba	Au (ppb)	Ga	Ni	Sc	V	Ce	Ge	La	Nd	Sm	Eu	Tb	Yb	Lu	Mo
[illegible]	10	150	10	980															
[illegible]	10	30	20	190															

EAST COOR.	NORTH COOR.	MAP SAMPLE #	ACTUAL SAMPLE #	MAP BLOCK	ROCK CODE	ROCK DESCRIPTION	REFERENCE NAME	REFERENCE YEAR	SiO2	Al2O3	Fe2O3	FeO	MgO	CaO
.87	54179.44	154	AN-3-16	M	2cp	dacite porphyry	Gleason	1986	53.00	16.50	2.49	5.70	4.86	3.2
.33	54228.73	155	AN-3-17	M	1a	basalt	Gleason	1986	48.50	13.60	2.15	7.69	6.70	13.9
.10	54708.92	156	AN-3-20	MN	4ef	volcaniclastic wacke	Gleason	1986	56.20	16.20	2.44	8.15	3.15	0.6
.53	54513.42	157	AN-3-21	M	1a	basalt	Gleason	1986	50.10	15.40	2.11	5.80	6.91	13.1
.60	54140.97	158	AN-3-22	M	1a	basalt	Gleason	1986	50.30	15.90	2.44	7.97	5.16	9.2
.90	54644.28	159	AN-3-23	MN	1.5a	andesite/dacite	Gleason	1986	55.90	18.20	2.24	4.20	5.28	1.4
.20	54502.83	160	AN-3-24	M	1a	basalt	Gleason	1986	53.80	14.30	2.22	5.62	7.21	6.8
6.30	54172.91	161	AN-3-26	M	1c	foliated gabbro	Gleason	1986	49.50	11.40	2.76	9.57	9.50	6.1
5.67	54193.72	162	AN-3-30	M	6b	granodiorite	Gleason	1986	64.20	16.00	1.92	2.29	2.36	1.0
9.15	54653.13	163	AN-3-31	MN	1.5a	andesite/dacite	Gleason	1986	64.00	15.70	2.17	3.59	3.39	0.3
8.03	54699.02	164	AN-3-32	MN	1.5a	andesite/dacite	Gleason	1986	64.10	15.30	2.14	3.56	3.80	0.4
9.35	54810.54	165	AN-3-34	MN	1.5a	andesite/dacite	Gleason	1986	58.40	13.90	2.24	4.58	6.90	1.7
4.49	54486.47	166	AN-3-35	M	6b	granodiorite	Gleason	1986	64.50	15.80	1.90	2.07	2.61	1.3
36.78	54090.51	167	AN-3-37	M	1a	basalt	Gleason	1986	47.70	15.00	2.40	8.73	8.59	9.2
68.69	54344.05	168	AN-3-38	M	1c	gabbro	Gleason	1986	49.00	14.90	2.77	10.28	4.77	7.7
02.92	54500.04	169	AN-3-39	M	2cp	dacite porphyry	Gleason	1986	62.60	16.10	1.90	1.96	2.15	3.1
09.36	54648.82	170	AN-3-40	M	1av	variolitic basalt	Gleason	1986	53.80	12.90	2.10	6.68	6.84	10.3
15.47	54550.97	171	AN-3-41	M	2cp	dacite porphyry	Gleason	1986	65.20	16.30	1.89	1.43	2.32	0.8
04.86	54647.69	172	AN-3-43	M	1.5a	andesite/dacite	Gleason	1986	57.60	14.00	2.44	6.69	2.70	6.1
15.38	54729.60	173	AN-3-44	MN	4ef	volcaniclastic wacke	Gleason	1986	65.20	15.70	2.11	2.70	2.86	1.6
73.87	54415.37	174	AN-3-46	M	1a	basalt	Gleason	1986	51.80	15.10	2.22	7.00	6.53	7.4
9.27	52170.77	175	KT-3-1	K	1a	basalt	Brozdowski	1986	46.60	13.40	2.39	8.65	10.50	5.5
9.60	53399.85	176	KT-3-2	M	1a	basalt	Brozdowski	1986	45.90	14.90	2.53	9.42	5.29	13.5
9.73	51955.12	177	KT-3-4	K	1a	basalt	Brozdowski	1986	73.90	15.60	2.07	-0.35	0.22	0.3
2.68	51933.73	178	KT-3-5	K	1.5a	andesite	Brozdowski	1986	57.80	16.50	2.21	8.54	3.35	0.7
6.35	52215.55	179	KT-3-6	K	2a	rhyodacite	Brozdowski	1986	68.20	14.80	1.93	1.32	1.79	1.1
7.20	53322.90	180	KT-3-12	B	1a	basalt	Brozdowski	1986	46.80	15.10	2.43	8.97	5.93	13.8
5.02	52894.24	181	KT-3-14	B	1a	basalt	Brozdowski	1986	47.60	13.00	2.83	12.39	5.09	10.9
7.42	53627.11	182	KT-3-17	K	2a	dacite	Brozdowski	1986	61.80	14.90	2.13	2.19	2.52	2.7
7.67	51815.69	183	KT-3-20	K	2a	rhyodacite	Brozdowski	1986	69.30	15.60	2.16	0.64	0.92	1.1
4.71	51703.12	184	KT-3-25	K	2a	dacite	Brozdowski	1986	66.20	15.50	2.08	3.70	2.60	1.2
9.63	52476.72	185	00859	K	1a	basalt	Brozdowski	1986	44.90	12.20	2.28	12.35	9.83	9.4
9.12	60586.84	186	FCT-1	S	8	keweenawan diabase dike	Callahan	1988	47.50	12.30	4.94	12.11	5.00	8.7
0.41	54751.23	187	1-3-1	N	2cp	qtz-fsp-porphyry	Gleason	1985	70.80	15.50	1.70	-0.31	0.55	1.9
2.55	59261.67	188	1-3-2	G	5a	Presque Isle peridotite	Gleason	1985	37.10	2.30	1.94	10.67	29.50	2.2
.74	52922.88	189	1-3-6	M	1c	fine grained gabbro	Gleason	1985	49.20	14.00	2.37	9.29	9.96	4.0
.37	53943.12	190	1-3-7	M	1c	fine grnd gabbro	Gleason	1985	55.50	13.70	2.77	9.29	4.97	5.0
.70	53557.97	191	1-3-9	M	1a	basalt	Gleason	1985	48.60	16.00	2.50	7.83	8.73	5.2
.80	47886.10	192	1-3-10	M	1a	basalt	Gleason	1985	47.50	15.50	2.41	7.19	4.06	10.8
.02	57575.22	193	1-3-12	G	1ac	carbonatized basalt	Gleason	1985	55.30	14.90	2.18	5.49	6.34	8.4
.07	57575.23	194	1-3-13	G	1a	very fn grnd basalt	Gleason	1985	51.40	12.70	3.69	10.72	4.83	8.3
.23	52335.34	195	1-3-15	M	1ap	pillow basalt	Gleason	1985	47.50	14.40	2.39	8.65	7.83	9.8
.60	52355.10	196	1-3-16	M	1c	fine grained gabbro	Gleason	1985	44.20	13.70	2.43	9.60	12.90	6.5
07	52101.69	197	1-3-17	M	1ac	carbonatized basalt	Gleason	1985	54.00	16.60	2.27	4.25	7.01	5.2
56	54595.55	198	1-3-19	M	4d	sericite-chlorite slate	Gleason	1985	48.00	15.00	2.42	8.35	8.00	8.8
70	52218.36	199	1-3-20	M	1as	foliated basalt	Gleason	1985	63.50	15.90	2.16	3.69	3.55	0.
58	54218.43	200	1-3-21	M	1ac	carbonatized basalt	Gleason	1985	49.20	14.40	2.48	7.76	8.96	11.0
37	53917.05	201	1-3-22	M	1av	variolitic basalt	Gleason	1985	51.40	11.90	2.69	8.92	7.72	9.2
52	56097.99	202	1-3-27	N	2bl	lapilli tuff	Gleason	1985	54.60	16.70	2.46	4.45	4.11	6.1
46	56245.57	203	1-3-28	N	1e	chlorite-feldspar amphibolite	Gleason	1985	48.20	14.80	2.20	8.73	8.37	10.8
.2	55005.38	204	1-3-29	N	1e	fsp-chlorite amphibolite	Gleason	1985	49.00	15.30	2.27	8.94	7.82	10.1
.8	55438.05	205	1-3-30	N	2a	chl-ser-qtz felsite	Gleason	1985	70.50	17.10	1.93	-0.12	1.37	0.7
09	55521.31	206	1-3-31	N	1e	amphibolite	Gleason	1985	48.80	15.10	2.29	9.46	7.23	11.
.0	55325.12	207	1-3-33	N	1e	pyroxene amphibole rock	Gleason	1985	47.70	15.10	2.52	9.88	7.29	10.8
.4	55089.85	208	1-3-35	N	2a	quartz-sericite tuff	Gleason	1985	72.10	16.00	1.72	-0.53	1.12	0.
33	57451.92	209	1-3-37	G	2a	plag-qtz-fsp granitoid	Gleason	1985	65.40	15.50	1.94	1.45	1.74	3.
29	56795.31	210	1-3-38	G	2a	muscovite-biotite felsic rk	Gleason	1985	71.90	15.60	1.71	-0.69	0.56	1.
45	56868.15	211	1-3-39	G	6f	diorite	Gleason	1985	49.40	16.00	2.52	8.53	6.58	6.
47	56865.11	212	1-3-40	G	2b	dacite tuff	Gleason	1985	64.00	14.90	2.15	4.06	3.82	0.
31	53573.99	213	2-3-1	M	1ac	carbonatized basalt	Gleason	1985	52.90	14.90	2.24	6.02	7.86	7.
27	53544.51	214	2-3-2a	M	1e	amphibolite	Gleason	1985	43.50	9.71	2.25	10.75	18.40	7.
26	53541.45	215	2-3-2b	M	1ap	pillow basalt	Gleason	1985	50.80	14.20	2.46	7.32	7.11	8.
20	53538.41	216	2-3-2c	M	1e	bladed amphibolite	Gleason	1985	49.80	13.70	3.26	11.46	4.92	8.
26	51980.84	217	2-3-8	M	4d	qtz-ser-chl slate	Gleason	1985	47.60	16.50	2.54	8.60	8.02	2.
.75	54705.724	218	2-3-12	M	1a	basalt	Gleason	1985	51.60	15.20	2.62	8.71	8.23	2.
.25	52635.62	219	2-3-15	M	1a	basalt	Gleason	1985	49.00	15.00	2.86	8.67	6.26	5.
.02	52490.75	220	2-3-21	M	1e	amphibolite	Gleason	1985	49.50	12.70	3.13	13.38	5.87	5.
.33	53911.82	221	2-3-22	M	6e	syenite	Gleason	1985	56.20	16.10	2.33	4.71	5.00	4.
.14	54204.63	222	2-3-23	D	6f	diorite	Gleason	1985	54.10	15.10	2.49	4.58	5.61	5.
.21	55589.82	223	2-3-25	D	6e	syenite	Gleason	1985	66.00	15.70	1.96	1.15	2.69	0.
.11	57184.89	224	2-3-26	MN	2bf	qtz-ser-chl schist	Gleason	1985	57.00	18.60	2.25	5.26	4.81	0.
.60	58323.18	225	2-3-27	S	1e	amphibolite	Gleason	1985	49.60	11.70	3.51	14.03	4.64	8.
.78	62568.73	226	2-3-28	N	1c	gabbro	Gleason	1985	49.10	16.60	2.01	6.66	7.19	11.
.48	62807.25	227	2-3-29	N	1e	amphibolite/peridotite	Gleason	1985	50.80	13.20	2.54	10.76	7.16	7.
.93	62951.06	228	2-3-30	N	2cp	qtz-fsp porphyry	Gleason	1985	68.60	15.50	1.91	1.25	1.72	1.
.01	56719.11	229	2-3-36	MN	4e	volcaniclastic sediment	Gleason	1985	65.70	14.10	2.21	3.50	3.63	0.
.07	53642.23	230	2-3-43	M	1as	foliated basalt	Gleason	1985	47.10	[illegible]	2.84	[illegible]	[illegible]	1.

EAST COOR.	NORTH COOR.	MAP SAMPLE #	ACTUAL SAMPLE #	MAP BLOCK	ROCK CODE	ROCK DESCRIPTION	REFERENCE NAME	REFERENCE YEAR	SiO2	Al2O3	Fe2O3	FeO	MgO	CaO
.72	55496.29	231	2-3-44	MN	4b	chl-qtz wacke	Gleason	1985	58.70	17.80	2.24	4.66	4.13	1.

	CaO	Na2O	K2O	TiO2	P2O5	MnO	LOI	H2O-	H2O+	CO2	SUM	Cr	Rb	Sr	Y	Zr	Nb	Ba	Au (ppb)	Ga	Ni	Sc	V	Ce	Ge
86	3.24	3.33	3.43	0.99	0.35	0.15	4.23				98.27	-68	-10	210	10	150	10	980							
70	13.90	0.49	1.68	0.65	0.07	[illegible]	3.00				98.61	205	40	80	10	30	20	190							
5	0.68	5.02	1.38	0.94	0.20	0.06	4.16				98.58	-68	60	250	100	500	40	330							
91	13.10	1.23	0.67	0.61	0.07	0.15	2.70				98.85	410	-10	160	20	30	20	120							
6	9.29	1.78	0.93	0.94	0.07	0.19	3.54				98.51	205	40	140	10	20	20	160							
28	1.40	5.19	1.66	0.74	0.16	0.08	3.77				96.82	137	60	270	20	120	20	470							
21	6.81	4.32	1.22	0.72	0.07	0.21	2.23				98.73	137	40	160	10	30	10	290							
50	6.15	2.57	1.28	1.26	0.12	0.17	3.85				98.13	68	30	60	30	70	30	310							
36	1.02	4.13	3.78	0.42	0.18	0.09	2.39				98.78	-68	120	210	20	140	-10	1190							
39	0.34	3.15	2.75	0.67	0.15	0.06	3.00				98.97	137	110	220	10	130	20	560							
30	0.42	2.99	2.79	0.64	0.16	0.07	2.93				98.90	137	100	160	10	120	20	550							
90	1.77	2.35	2.31	0.74	0.29	0.13	5.16				98.77	342	70	260	-10	130	10	760							
61	1.30	5.33	2.29	0.40	0.19	0.07	2.23				98.69	-68	70	250	20	140	20	670							
59	9.22	2.28	0.68	0.90	0.07	0.19	2.93				98.69	205	10	150	-10	50	40	100							
73	7.24	3.56	1.01	[illegible]	0.13	0.20	2.85				97.94	-68	60	310	20	90	20	230							
15	3.19	4.67	2.15	0.40	0.19	0.08	2.85				98.24	-68	80	590	-10	130	20	930							
84	10.30	1.77	0.92	0.60	0.07	0.24	1.70				97.92	410	50	110	10	20	20	390							
32	0.81	5.79	2.82	0.39	0.19	0.06	1.70				98.90	-68	80	320	20	130	10	720							
70	6.18	2.95	1.44	0.94	0.38	0.12	3.00				98.44	-68	50	600	40	250	20	580							
86	1.62	4.90	1.43	0.61	0.16	0.07	2.16				99.52	137	50	600	10	170	10	460							
53	7.48	2.96	0.63	0.72	0.07	0.25	4.39				99.15	410	30	110	10	30	20	190							
50	5.59	1.56	0.22	0.89	0.07	0.16	8.54				98.57	616	10	80	-10	40	30	100							
29	13.50	1.32	0.13	1.03	0.09	0.19	4.62				98.92	205	10	190	30	40	40	20							
22	0.37	0.80	3.53	0.57	0.16	0.03	2.23				99.13	68	150	100	30	150	30	410							
35	0.75	2.87	2.09	0.71	0.19	0.11	3.77				98.89	68	50	30	20	120	20	230							
79	1.18	4.77	1.54	0.43	0.13	0.05	2.77				99.21	68	90	110	-10	140	10	280							
93	13.80	2.06	0.40	0.93	0.10	0.26	2.08				98.86	274	30	70	20	40	20	100							
09	10.90	1.86	0.58	1.33	0.13	0.27	1.62				97.60	-68	30	150	20	90	30	130							
52	2.73	2.72	3.99	0.63	0.19	0.10	4.77				98.67	-68	110	70	20	170	20	650							
92	1.11	6.59	1.35	0.66	0.18	0.07	1.62				100.20	68	40	360	10	160	20	410							
60	1.27	0.55	2.66	0.58	0.20	0.07	4.00				99.41	68	90	80	10	150	30	320							
83	9.44	1.10	0.67	0.78	0.08	0.28	4.77				98.68	137	10	90	10	30	30	180							
00	8.74	2.08	0.84	3.44	0.40	0.23	1.16				98.74	137	-10	191	-10	218	39	327							
55	1.98	5.78	1.90	0.20	0.06	0.03	2.00				100.19	-68	60	630	-10	90	10								
50	2.24	0.21	0.10	0.44	0.05	0.18	11.80				96.53	6498	20	50	-10	-10	10								
96	4.09	3.44	0.79	0.87	0.08	0.21	3.70				98.00	68	10	80	30	40	-10								
97	5.07	2.00	0.54	1.27	0.14	0.18	3.62				99.05	-68	-10	120	20	130	10								
73	5.27	1.23	0.93	1.00	0.08	0.33	7.00				[illegible]0	205	30	100	20	40	20								
06	10.80	3.20	0.18	0.91	0.07	0.18	7.00				[illegible].00	205	20	190	-10	30	20		1						
34	8.41	3.17	0.15	0.68	0.07	0.17	2.47				[illegible].33	479	20	100	20	30	10		3						
83	8.38	-0.01	0.17	2.19	0.27	0.24	4.47				99.05	-68	10	180	40	220	40		2						
63	9.85	2.35	0.75	0.89	0.07	0.19	3.47				98.34	205	20	130	-10	20	20		3						
90	6.56	1.53	0.85	0.93	0.08	0.23	5.23				98.24	616	40	130	10	30	20		2						
01	5.24	5.03	0.34	0.77	0.08	0.15	3.08				98.82	479	20	120	-10	50	20		1						
00	8.82	2.90	0.36	0.92	0.07	0.19	3.08				98.11	205	-10	70	10	30	40								
55	0.40	3.08	3.49	0.66	0.16	0.04	3.16				99.79	68	90	90	10	130	10								
96	11.00	1.38	0.44	0.68	0.07	0.20	2.93				99.20	410	20	110	20	40	20		5						
72	9.21	1.37	1.21	1.19	0.11	0.21	2.39				98.32	342	-10	150	20	70	10		3						
11	6.18	4.49	2.04	0.96	0.51	0.11	1.47				98.08	68	-10	650	40	300	20		8						
37	10.80	2.31	0.70	0.70	0.06	0.19	2.00				99.06	205	30	170	10	20	-10		3						
82	10.10	1.35	0.61	0.77	0.07	0.18	2.39				98.80	205	-10	130	10	50	10		4						
37	0.28	0.62	5.23	0.43	0.12	0.02	2.77				100.25	-68	140	110	-10	100	10		1						
23	11.20	1.39	0.35	0.79	0.07	0.20	1.54				98.42	137	20	80	20	20	20		18						
29	10.80	2.07	0.43	1.02	0.11	0.20	1.93				99.05	205	20	100	10	30	10								
12	0.86	3.56	3.43	0.22	0.06	0.01	2.00				100.55	-68	80	200	10	90	10		2						
74	3.55	5.30	1.73	0.44	0.12	0.05	2.85				100.07	-68	50	640	30	100	-10								
56	1.35	5.68	2.93	0.21	0.06	0.01	1.16				100.48	-68	60	560	-10	90	-10								
58	6.41	2.17	1.48	1.02	0.09	0.21	4.39				98.80	68	40	200	-10	40	-10								
82	0.66	4.06	1.73	0.65	0.16	0.09	3.16				99.44	137	-10	210	10	120	30								
86	7.61	2.70	0.54	0.74	0.08	0.25	3.23				99.07	821	30	110	20	40	10		4						
40	7.12	0.22	0.05	0.75	0.07	0.25	5.39				98.46	1847	20	-10	-10	40	30								
11	8.61	3.16	1.49	0.96	0.08	0.18	2.39				98.76	342	50	270	90	50	-10								
92	8.63	2.06	0.79	1.76	0.19	0.21	2.47				99.25	-68	-10	140	40	130	20								
02	2.94	1.35	2.45	1.04	0.08	0.17	8.16				99.45	274	20	-10	20	30	10		17						
23	2.94	3.25	0.51	1.12	0.11	0.17	4.93				99.39	68	10	70	-10	50	30		5						
26	5.19	0.46	3.08	1.36	0.11	0.24	7.23				99.46	137	10	70	30	60	10		1						
87	5.63	2.51	0.77	1.63	0.12	0.21	2.93				98.38	-68	40	100	30	70	40								
00	4.40	4.46	2.31	0.83	0.34	0.10	2.39				99.17	68	70	700	10	160	10		3						
61	5.26	3.93	4.28	0.99	0.52	0.11	1.93				98.90	68	160	970	30	270	20								
69	0.77	4.48	4.15	0.46	0.17	0.07	2.23				99.83	68	90	470	-10	150	20		4						
81	0.42	2.65	3.87	0.75	0.17	0.08	3.85				99.71	137	110	90	20	100	40		1						
64	8.43	2.12	0.21	2.01	0.15	0.23	1.31				97.94	-68	30	100	20	90	10		5						
19	11.10	2.21	1.35	0.51	0.05	0.14	1.85				98.77	547	50	190	10	-10	10								
16	7.99	2.37	0.94	1.04	0.09	[illegible]	1.62				98.72	68	30	[illegible]	30	40	20								
72	1.86	5.41	1.91	0.41	0.12	0.05	1.47				100.21	68	50	310	10	110	10		4						
63	0.80	2.76	2.51	0.71	0.16	[illegible]	[illegible]				[illegible]	205	70	270	10	160	10		5						
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]	290	10	[illegible]	[illegible]								

	CaO	Na2O	K2O	TiO2	P2O5	MnO	LOI	H2O-	H2O+	CO2	SUM	Cr	Rb	Sr	Y	Zr	Nb	Ba	Au (ppb)	Ga	Ni	Sc	V	Ce	Ge
[illegible]	1.79	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.47				[illegible]	137	90	510	10	160	[illegible]								

6?	-10	210	10	150	10	980	
05	40	80	10	30	20	190	
69	60	250	100	500	40	330	
11?	-10	160	20	30	20	120	
05	40	140	10	20	20	160	
37	60	270	20	120	20	470	
37	40	160	10	30	10	290	
68	30	60	30	70	30	310	
68	120	210	20	140	-10	1190	
37	110	220	10	130	20	560	
137	100	160	10	120	20	550	
342	70	260	-10	130	10	760	
68	70	250	20	140	20	670	
205	10	150	-10	50	40	100	
?8	60	310	20	90	20	230	
-68	80	590	-10	130	20	930	
4?0	50	110	10	20	20	390	
-68	80	320	20	130	10	720	
-68	50	600	40	250	20	580	
137	50	600	10	170	10	460	
410	30	110	10	30	20	190	
616	10	80	-10	40	30	100	
2?5	10	190	30	40	40	20	
68	150	100	30	150	30	410	
68	50	30	20	120	20	230	
68	90	110	-10	140	10	280	
274	30	70	20	40	20	100	
-68	30	150	20	90	30	130	
-68	110	70	20	170	20	650	
68	40	360	10	160	20	410	
68	90	80	10	150	30	320	
137	10	90	10	30	30	180	
37	-10	191	-10	218	39	327	
-68	60	630	-10	90	10		
98	20	50	-10	-10	10		
68	10	80	30	40	-10		
-68	-10	120	20	130	10		
2?5	30	100	20	40	20		
??5	20	190	-10	30	20		1
479	20	100	20	30	10		3
-68	10	180	40	220	40		2
?05	20	130	-10	20	20		3
?16	40	130	10	30	20		2
1??	20	120	-10	50	20		1
2?5	-10	70	10	30	40		
?8	90	90	10	130	10		
??0	20	110	20	40	20		5
?4?	-10	150	20	70	10		3
?8	-10	650	40	300	20		8
?5	30	170	10	20	-10		3
?05	-10	130	10	50	10		4
?8	140	110	-10	100	10		1
?7	20	80	20	20	20		18
?5	20	100	10	30	10		
?8	80	200	10	90	10		2
68	50	640	30	100	-10		
68	60	560	-10	90	-10		
??	40	200	-10	40	-10		
37	-10	210	10	120	30		
??	30	110	20	40	10		4
47	20	-10	-10	40	30		
42	50	270	90	50	-10		
68	-10	140	40	1?0	20		
74	20	-10	20	30	10		17
?8	10	70	-10	50	30		5
77	10	70	30	60	10		1
68	40	100	30	70	40		
?8	70	700	10	160	10		3
?8	160	970	30	270	20		
?8	90	470	-10	150	20		4
?7	110	90	20	100	40		1
?8	30	100	20	90	10		5
47	50	190	10	-10	10		
?8	30	70	30	40	20		
?8	50	310	10	110	10		4
??	70	270	10	160	10		5
?	20	290	10	80	30		

	Rb	Sr	Y	Zr	Nb	Ba	Au (ppb)	Ga	Ni	Sc	Y	Ce	Ge	La	Nd	Sm	Eu	Tb	Yb	Lu	Mo
?7	90	530	10	150	10																
8	50	250	-10	80	20		4														
?5	110	520	10	110	10																
?8	30	150	-10	150	-10																

572.72	55496.29	231	2-3-44	MN	4b	chl-qtz wacke	Gleason	1985	58.70	17.80	2.24	4.66	4.13	
3836.30	57619.52	232	2-3-46	MS	2b	Sheared Rhyolite tuff	Gleason	1985	72.70	15.00	1.74	0.00	1.24	
4.06.01	55032.42	233	2-3-49	MN	4b	chl-ser felsic wacke	Gleason	1985	61.90	15.90	2.15	3.72	3.92	
3325.73	52281.20	234	2-3-50	K	2b	dacite tuff	Gleason	1985	64.70	14.80	2.16	2.92	5.21	
3222.30	52980.83	235	2-3-53	M	1a	basalt	Gleason	1985	47.10	15.40	2.55	8.50	8.09	
1065.10	53247.08	236	2-3-62	M	1ac	carbonated basalt	Gleason	1985	54.20	16.10	2.24	4.98	6.34	
4090.01	58864.54	237	2-3-72	S	4em	volcanic wacke	Gleason	1985	50.30	17.80	2.87	10.19	4.98	
8524.62	51207.17	238	3-3-1	K	2b	dacite tuff	Gleason	1985	60.70	16.50	2.17	2.60	2.96	
7027.43	54159.45	239	3-3-8	K	2b	dacite tuff	Gleason	1985	64.10	18.80	2.15	4.85	0.69	
7027.45	54162.51	240	3-3-9	K	2b	dacite tuff	Gleason	1985	65.60	15.40	2.15	3.33	3.71	
7030.59	54171.65	241	3-3-10	K	2b	dacite tuff	Gleason	1985	66.00	18.70	2.11	2.36	1.26	
5861.45	50588.97	242	3-3-13	K	2b	dacite tuff	Gleason	1985	66.60	14.50	2.13	3.03	3.70	
5300.63	50389.19	243	3-3-14	K	2bf	dacite tuff breccia	Gleason	1985	61.40	15.50	2.17	3.21	4.16	
5450.60	53754.74	244	3-3-17	B	2b	dacite	Gleason	1985	64.80	16.10	2.15	2.35	3.10	
6326.55	44917.612	245	3-3-18	B	2b	dacite xl tuff	Gleason	1985	62.50	16.80	2.14	2.73	2.49	
3316.84	44969.448	246	3-3-19	B	2b	rhyodacite tuff	Gleason	1985	70.00	14.40	2.04	0.71	1.38	
4521.40	53356.55	247	3-3-20	B	1a	basalt	Gleason	1985	42.90	6.47	1.98	8.30	24.50	
4518.41	53362.69	248	3-3-21	B	2b	rhyodacite dike or tuff	Gleason	1985	65.20	15.20	2.13	2.50	2.81	
3575.26	52775.21	249	3-3-28	B	1e	amphibolite	Gleason	1985	49.70	13.70	2.59	8.83	7.52	
2928.78	51894.87	250	3-3-32	B	1e	amphibolite	Gleason	1985	47.90	13.90	2.01	12.59	5.55	
2928.78	51894.87	251	3-3-35	B	1a	basalt	Gleason	1985	44.70	16.90	2.55	9.76	8.43	
1993.79	53239.36	252	9-7-6-23	B	1as	basalt	Maclellan	1988	61.30	16.20	2.19	2.79	3.21	
2655.47	54072.633	253	9-7-6-24	S	1as	highly altered & foliated basalt	Maclellan	1988	51.22	13.99	3.52	14.38	7.89	
3777.99	53153.964	254	8-19-6-8	S	1as	highly altered & foliated basalt	Maclellan	1988	55.42	15.53	2.57	5.35	5.93	
811.20	59079.47	255	8-18-1-21	S	1as	highly altered & foliated basalt	Maclellan	1988	44.59	10.68	2.25	6.23	7.52	
555.34	58182.657	256	1011-7-10	R	1asp	foliated pillowed basalt	Maclellan	1988	50.16	12.88	2.43	10.28	7.75	
547.86	58020.836	257	9-1-7-9	R	1asp	foliated pillowed basalt	Maclellan	1988	50.99	11.83	4.66	14.90	7.98	
750.28	58111.039	258	11-4-7-12	R	2a	foliated rhyolite	Maclellan	1988	71.02	16.12	1.77	0.48	1.66	
913.64	60658.07	259	818-36-17	S	1c	Clark Creek gabbro	Maclellan	1988	48.36	11.57	3.04	14.97	7.10	
021.24	60807.12	260	818-36-14	S	1c	Clark Creek gabbro	Maclellan	1988	49.31	14.75	2.18	8.64	9.57	
276.11	59235.97	261	7-28-1-8	S	6b	Dead River Pluton granodiorite	Maclellan	1988	64.16	15.64	1.99	2.38	3.53	
449.82	59224.82	262	8-20-1-35	S	6b	Dead River Pluton granodiorite	Maclellan	1988	67.23	16.48	1.89	1.33	1.77	
961.42	60633.20	263	6-25-16	S	1c	gabbroic clast in breccia	Maclellan	1988	50.27	12.40	3.27	9.66	8.53	
945.39	60539.45	264	8-31-31-10	N	6b	granodioritic clast in breccia	Maclellan	1988	69.07	15.02	1.95	1.62	2.08	
967.48	60630.07	265	6-25-1a	S	2bf	rhyolitic clast in breccia	Maclellan	1988	65.84	15.26	2.00	2.08	3.76	
819.23	60726.46	266	831-36-21	S	1a	basalt	Maclellan	1988	50.55	12.41	2.76	7.90	10.40	
801.46	61437.60	267	831-31-15	N	1ap	pillowed basalt	Maclellan	1988	50.78	12.77	2.20	8.38	8.91	
525.16	60973.43	268	812-36-11	S	1ap	pillowed basalt	Maclellan	1988	49.00	14.57	2.51	9.24	8.18	
215.91	61232.02	269	831-31-16	N	1ap	pillowed basalt	Maclellan	1988	50.26	14.41	2.31	8.93	7.68	
764.18	60959.23	270	812-36-11	N	1ap	pillowed basalt	Maclellan	1988	49.62	12.81	2.45	11.30	8.87	
575.77	58754.89	271	8-19-1-30	R	2a	rhyolite intrusive of Fire Center Mine	Maclellan	1988	54.56	22.75	2.19	3.38	7.71	
260.49	59175.82	272	8-19-6-13	R	2a	rhyolite intrusive of Fire Center Mine	Maclellan	1988	74.95	14.01	1.72	0.35	0.99	
18.47	59007.27	273	8-19-1-26	S	2a	rhyolite intrusive of Fire Center Mine	Maclellan	1988	70.32	15.02	1.89	1.37	2.10	
83.71	59152.18	274	8-18-1-28	N	4j	Reany Creek arkose	Maclellan	1988	66.98	16.65	1.92	2.08	3.70	
62.36	62364.95	275	86-110	S	1a	basalt	Baxter	1988	47.35	10.80	4.30	7.12	9.20	
14.58	52945.20	276	RISO-14	B	2bm	qtz-ser-chl rock	Brozdowski	1988	37.70	25.00	2.71	6.10	11.00	
14.58	52945.20	277	RISO-15	B	2bm	qtz-ser-chl rock	Brozdowski	1988	60.00	17.30	2.23	3.76	6.04	
14.58	52945.20	278	RISO-19	B	2bm	qtz-ser-chl rock	Brozdowski	1988	62.00	15.70	2.17	2.94	5.34	
14.58	52945.20	279	RISO-22	B	2bm	qtz-ser-chl rock	Brozdowski	1988	30.60	17.60	2.16	5.11	11.10	
14.58	52945.20	280	RISO-16	B	2bm	qtz-ser-chl rock (lamprophyre?)	Brozdowski	1988	38.00	25.10	2.79	2.89	13.60	
14.58	52945.20	281	RISO-48	B	2bm	qtz-ser-chl rock	Brozdowski	1988	50.50	5.93	1.81	3.23	12.60	
14.58	52945.20	282	RISO-18	B	2bm	qtz-ser-chl rock	Brozdowski	1988	51.90	15.00	2.82	5.29	11.70	
14.58	52945.20	283	RISO-47	B	2bm	qtz-ser-chl rock	Brozdowski	1988	52.30	11.50	2.20	4.26	7.41	
14.58	52945.20	284	RS-16-659	B	2bm	qtz-ser-chl rock	Brozdowski	1988	57.60	15.30	2.24	3.95	10.70	
14.58	52945.20	285	RISO-30	B	2bm	qtz-ser-chl rock	Brozdowski	1988	59.20	14.70	2.32	3.01	10.00	
14.58	52945.20	286	RISO-27	B	2bm	qtz-ser-chl rock	Brozdowski	1988	61.90	15.30	1.97	2.60	8.86	
14.58	52945.20	287	RISO-44	B	2bm	qtz-ser-chl rock	Brozdowski	1988	62.50	13.20	2.17	4.26	8.30	
14.58	52945.20	288	RS-16-750	B	2bm	qtz-ser-chl rock	Brozdowski	1988	62.50	17.80	2.06	1.81	5.45	
14.58	52945.20	289	RS-26-126	B	2bm	qtz-ser-chl rock	Brozdowski	1988	62.70	17.20	2.22	1.19	6.04	
14.58	52945.20	290	RS-26-145	B	2bm	qtz-ser-chl rock	Brozdowski	1988	63.30	13.90	2.35	3.74	6.42	
14.58	52945.20	291	RISO-32	B	2bm	qtz-ser-chl rock	Brozdowski	1988	64.50	12.10	2.08	3.42	9.24	
14.58	52945.20	292	RISO-43	B	2bm	qtz-ser-chl rock	Brozdowski	1988	66.80	15.60	2.13	2.17	3.58	
14.58	52945.20	293	RS-16-786	B	2bm	qtz-ser-chl rock	Brozdowski	1988	68.30	13.40	1.93	1.82	4.64	
.58	52945.20	294	RISO-25	B	2bm	qtz-ser-chl rock	Brozdowski	1988	79.40	3.16	1.62	1.66	2.10	
.58	52945.20	295	RISO-42	B	2bm	qtz-ser-chl rock	Brozdowski	1988	79.40	4.49	1.74	0.72	2.24	
.58	52945.20	296	RISO-41	B	2bm	qtz-ser-chl rock	Brozdowski	1988	84.20	3.13	1.61	0.49	3.99	
.58	52945.20	297	RS-26-166	P	5ad	cb-qtz-chl rock	Brozdowski	1988	13.20	1.22	1.57	2.15	18.80	2
.58	52945.20	298	RS-16-42	P	5ad	cb-qtz-chl rock	Brozdowski	1988	29.30	0.89	1.54	2.17	24.00	1
.58	52945.20	299	RISO-49	P	5ad	cb-qtz-chl rock	Brozdowski	1988	36.30	2.07	1.60	3.69	20.90	1
.58	52945.20	300	RS-26-113	P	5ad	cb-qtz-chl rock	Brozdowski	1988	37.80	3.81	1.67	4.03	14.20	1
.58	52945.20	301	RS-16-291	P	5ad	cb-qtz-chl rock	Brozdowski	1988	55.00	0.79	1.55	2.54	22.70	
.58	52945.20	302	RS-16-162	P	5ad	cb-qtz-chl rock	Brozdowski	1988	56.40	1.48	1.57	3.01	28.80	
.58	52945.20	303	RS-16-226	P	5at	carbonate talc rock	Brozdowski	1988	27.90	1.49	1.59	2.81	37.10	
.58	52945.20	304	RS-26-191	P	5at	carbonate talc rock	Brozdowski	1988	29.00	1.82	1.58	3.85	25.00	1
.58	52945.20	305	RS-16-477	P	5at	carbonate talc rock	Brozdowski	1988	30.40	0.64	1.54	4.51	29.20	
.58	52945.20	306	RISO-45	P	5at	carbonate talc rock	Brozdowski	1988	34.50	1.47	1.58	3.36	25.40	1
.58	52945.20	307	RISO-50	P	5at	carbonate talc rock	Brozdowski	1988	35.80	3.19	1.65	5.97	24.30	

R.	NORTH COOR.	MAP SAMPLE #	ACTUAL SAMPLE #	MAP BLOCK	ROCK CODE	ROCK DESCRIPTION	REFERENCE NAME	REFERENCE YEAR	ELEMENTS SiO2	Al2O3	Fe2O3	FeO	MgO	C
58	52945.20	308	RISO-51	P	5a	serpentinized peridotite	Brozdowski	1988	12.40	0.36	1.54	5.93	35.20	
58	52945.20	309	RS-26-259	P	5a	serpentinized peridotite	Brozdowski	1988	29.40	0.33	1.53	4.69	32.80	
58	52945.20	310	RISO-46	P	5a	serpentinized peridotite	Brozdowski	1988	35.40	[illegible]	1.57	[illegible]	[illegible]	
58	52945.20	311	RS-16-548	P	5a	serpentinized peridotite	Brozdowski	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
32	53236.92	312	DLP-1-276.5	P	5a	serpentinized [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	

MgO	CaO	Na2O	K2O	TiO2	P2O5	MnO	LOI	H2O-	H2O+	CO2	SUM	Cr	Rb	Sr	Y	Zr	Nb	Ba	Au (ppb)	Ga	Ni	Sc	V	Ce	Ge
4.13	1.79	3.55	3.27	0.74	0.18	0.08	2.47				99.61	137	90	530	10	150	10								
1.24	0.26	4.75	2.66	0.24	0.06	0.02	1.70				100.37	-68	50	250	-10	80	20		4						
3.92	1.58	2.82	3.44	0.65	0.18	0.07	2.47				98.80	205	110	520	10	110	10								
5.21	0.52	4.60	0.52	0.66	0.18	0.03	3.08				99.38	68	30	150	-10	150	-10								
8.09	9.43	2.39	0.19	1.05	0.08	0.18	3.47				98.43	274	-10	140	100	40	10		5						
6.34	8.84	3.67	0.51	0.74	0.07	0.16	1.93				99.78	479	20	110	40	30	-10		10						
4.98	1.36	1.68	3.79	1.37	0.12	0.17	4.31				98.94	205	-10	50	-10	60	20		17						
2.96	2.97	0.52	4.40	0.67	0.22	0.11	6.31				100.13	-68	130	60	10	160	10		4						
0.69	0.04	0.09	4.74	0.65	0.04	0.02	3.23				99.40	68	160	30	10	150	-10		-1						
3.71	0.49	2.81	2.33	0.65	0.29	0.06	2.93				99.75	68	60	30	-10	120	20		-1						
1.26	0.09	0.16	5.61	0.61	0.07	0.03	3.00				100.02	-68	160	-10	10	150	10		1						
3.70	0.38	2.91	2.75	0.63	0.16	0.06	2.93				99.78	68	50	100	10	130	10		2						
4.16	1.58	0.95	5.01	0.67	0.20	0.12	4.93				99.90	68	-10	40	20	130	20		3						
3.10	0.57	3.36	3.67	0.65	0.18	0.05	2.70				99.68	-68	90	100	30	150	20		4						
2.49	2.10	4.38	2.87	0.64	0.17	0.06	3.16				100.04	-68	100	200	10	150	10		7						
1.38	1.48	4.32	2.57	0.54	0.12	0.05	2.47				100.08	-68	80	210	10	120	-10		-1						
4.50	4.11	1.02	0.40	0.48	0.04	0.13	7.54				97.87	3283	-10	40	10	-10	30		-1						
2.81	2.68	5.58	0.89	0.63	0.16	0.08	2.00				99.86	-68	40	80	20	120	20		3						
7.52	8.76	3.10	0.98	1.09	0.09	0.22	1.85				98.43	205	-10	110	10	50	20		2						
5.55	11.30	1.27	0.68	0.51	0.09	0.25	2.62				98.67	-68	10	180	-10	80	10		3						
8.43	10.30	0.10	0.11	1.05	0.09	0.18	4.54				98.71	205	10	650	20	60	10		3						
3.21	2.37	6.19	1.42	0.69	0.19	0.08	3.16				99.79	68	30	220	30	130	10		6						
7.89	0.76	3.06	1.29	2.02	0.11	0.16	4.71				103.11		19	42	20	72	8	368			106		457		
5.93	7.87	4.03	1.38	1.07	0.09	0.15	6.28				105.67		36	102	18	44	7	150			201		252		
7.52	24.20	2.02	0.60	0.75	0.24	0.23	15.59				114.90		9	53	15	28	7	5			159		214		
7.75	10.74	2.33	1.02	0.93	0.11	0.23	3.93				102.79		27	294	17	53	7	126			168		218		
7.98	2.23	1.22	0.81	3.16	0.35	0.22	5.21				103.56		-2	41	24	174	12	202			40		682		
1.66	0.21	5.64	2.68	0.27	0.07	0.03	1.34				101.29		46	184	8	79	11	465			25		42		
7.10	7.94	3.16	0.25	1.54	0.14	0.25	2.11				100.43		-2	84	19	55	9	79			28		364		
9.57	10.82	1.93	0.90	0.68	0.10	0.17	1.72				100.77		7	177	15	38	5	55			80		174		
.53	3.01	4.63	3.50	0.49	0.33	0.08	2.53				102.27		68	270	15	172	14	867			14		74		
.77	1.26	4.77	4.47	0.39	0.20	0.05	1.83				101.67		102	284	17	157	13	1177			16		62		
8.53	9.43	2.25	0.95	1.77	0.20	0.19	2.90				101.82		16	179	23	99	8	195			64		383		
2.08	3.51	4.59	1.20	0.45	0.28	0.05	1.98				101.80		32	542	12	173	15	605			39		69		
3.76	4.29	4.65	1.07	0.50	0.26	0.06	2.32				102.09		28	499	11	148	11	419			44		79		
.40	9.15	2.97	1.24	1.26	0.32	0.17	4.14				103.27		18	459	20	146	8	729			68		266		
8.91	12.99	1.28	0.79	0.70	0.09	0.18	2.29				101.36		13	160	14	34	8	70			180		161		
.18	11.22	1.36	1.62	1.01	0.10	0.17	4.64				103.62		28	103	17	40	6	236			154		237		
7.68	10.20	2.96	1.15	0.81	0.12	0.20	1.80				100.83		28	160	16	38	8	160			191		188		
8.87	10.22	1.77	0.41	0.95	0.12	0.22	2.32				101.06		3	118	16	38	7	106			141		220		
.71	0.08	0.33	7.81	0.69	0.11	0.03	4.34				103.98		216	21	29	174	15	1046			27		139		
.99	0.35	5.05	2.20	0.22	0.07	0.03	1.35				101.29		54	87	9	111	18	239			5		25		
.10	1.55	4.36	2.65	0.39	0.12	0.09	3.26				103.12		61	97	12	106	11	616			18		52		
.70	0.38	5.03	2.47	0.42	0.11	0.04	0.74				100.52		61	140	12	94	13	494			28		76		
.20	9.47	1.64	1.16	2.80	0.67	0.13					94.66		34	326	34	76	5	149			140		159		
.00	0.69	0.17	6.35	1.21	0.37	0.07	8.00		5.10	0.40	99.37	40	200	10	20	260	10		2084	23	58	21.70	200	103	10
.04	0.31	0.14	4.31	0.73	0.21	0.04	4.85		3.30	0.10	99.92	50	160	5	5	150	20		280	13	56	13.30	120	61	
.34	0.81	0.16	4.37	0.67	0.21	0.05	4.93		3.10	0.90	99.35	40	140	20	10	130	20		1524	19	28	13.30	110	66	10
.10	8.09	0.20	4.52	0.66	0.26	0.36	13.00		2.90	12.30	93.66	10	140	50	30	120	10		4479	18	46	12.70	150	82	
.60	2.07	0.15	5.12	1.29	1.58	0.03	7.62		4.60	0.10	100.24	140	170	70	60	410	20		56204	22	150	23.00	200	376	10
.60	8.53	0.08	0.10	0.31	0.18	0.15	13.50		3.10	12.20	96.92	490	20	190	20	90	20		31	7	360	10.40	70	120	10
.70	0.84	0.75	2.82	1.32	0.15	0.06	6.47		5.20	1.10	99.12	130	60	30	40	80	10		93	15	120	51.80	370	36	
.41	6.33	0.10	2.54	0.70	0.20	0.12	11.20		2.90	8.90	98.86	600	100	80	40	100	10		31	14	140	18.60	150	42	10
.70	0.28	0.11	2.17	0.74	0.19	0.03	5.77		4.40	0.09	99.08	190	70	5	10	130	20		31	15	160	19.00	130	70	
.00	1.31	0.11	2.30	0.82	0.93	0.05	5.08		4.40	0.09	99.83	110	120	50	20	240	30		62	14	100	14.40	140	210	10
.86	0.20	0.12	3.18	0.47	0.13	0.03	4.93		3.90	0.10	99.69	60	130	20	5	130	30		8087	18	51	8.80	92	40	
.30	0.24	0.12	2.21	0.67	0.15	0.05	5.08		4.00	0.10	98.95	180	90	5	10	110	5		31	13	120	15.8	120	35	10
.45	0.23	0.16	4.49	0.56	0.12	0.02	4.47		3.00	0.09	99.67	110	150	10	5	160	10		31	20	58	7.2	84	49	
.04	0.37	0.14	4.63	0.72	0.17	0.01	4.39		3.30	0.20	99.78	100	150	10	5	100	20		31	19	130	17.4	120	41	
.42	0.37	0.11	3.12	0.85	0.14	0.01	5.00		3.20	0.20	99.31	140	100	5	10	80	20		31	14	190	20.8	180	63	
.24	0.14	0.1[illegible]	1.93	0.58	0.10	0.02	5.16		3.90	0.09	99.39	170	90	10	5	120	10		3452	11	120	12.6	150	46	20
.58	0.36	0.14	4.29	0.63	0.25	0.01	3.77		2.70	0.10	99.73	110	140	10	20	150	10		31	19	170	11.6	98	59	[illegible]
.64	0.57	0.13	3.33	0.43	0.05	0.02	4.00		2.60	1.00	98.62	60	100	5	5	130	5		31	15	71	7.5	72	36	
.10	1.72	0.13	0.78	0.12	0.04	0.05	3.77		0.70	2.80	94.55	170	5	10	5	20	40		3701	4	71	2.4	36	1	
.24	2.44	0.08	0.36	0.24	0.04	0.04	3.47		0.90	3.60	95.26	150	5	50	5	30	10		31	6	38	4	46	16	
.99	1.62	0.07	0.16	0.11	0.05	0.04	3.16		1.60	2.20	98.63	140	20	5	5	5	10			3	44	2.8	40	9	
.80	25.00	0.08	0.02	0.07	0.02	0.11	38.10		0.09	37.10	100.34	280	10	530	5	5	20			2	290	4.8	30	7	
.00	14.30	0.07	0.01	0.04	0.02	0.09	27.90		1.90	25.90	100.33	880	20	420	10	5	20			2	1100	5.1	32	1	
.90	13.06	0.08	0.01	0.10	0.02	0.10	21.10		1.20	19.60	98.97	1080	20	330	5	5	10			3	1300	9.2	48	3	
.20	14.50	0.09	0.02	0.17	0.02	0.21	22.40		2.20	21.10	98.92	1180	20	190	5	20	10			5	940	13.4	74	4	
.70	0.98	0.13	0.01	0.05	0.01	0.04	14.60		1.70	14.00	98.40	1450	10	5	5	5	5			2	1700	4.9	36	3	
.80	0.67	0.07	0.01	0.07	0.01	0.02	6.00		3.70	1.30	98.11	1080	40	10	5	5	20			3	2600	5.4	50	6	
.10	0.30	0.10	0.01	0.09	0.01	0.15	28.40		2.30	25.10	99.95	750	10	5	5	5	20			2	2900	10	28	2	
.00	14.10	0.10	0.01	0.08	0.02	0.11	23.80		2.80	21.00	99.47	1660	10	250	10	5	20			2	2400	7.3	38	2	
.20	9.37	0.09	0.01	0.04	0.01	0.11	23.80		2.20	22.50	99.72	2480	10	120	5	5	20			1	2700	5.2	[illegible]	1	
.40	11.80	0.08	0.01	0.08	0.02	0.18	20.30		3.00	18.20	98.78	2010	5	-210	10	5	10			3	2200	7.6	34	3	
.30	9.48	0.09	0.01	0.15	0.02	0.18	17.60		3.70	14.20	98.64	2450	10	150	5	5	10			4	1700	14	66	[illegible]	

O	CaO	Na2O	K2O	TiO2	P2O5	MnO	LOI	H2O-	H2O+	CO2	SUM	Cr	Rb	Sr	Y	Zr	Nb	Ba	Au (ppb)	Ga	Ni	Sc	V	Ce	Ge
.20	6.61	0.09	0.02	[illegible]	0.02	0.17	37.00		[illegible]	[illegible]	99.38	3200	5	190	5	5	10			[illegible]	[illegible]	[illegible]	[illegible]		
.80	4.84	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	25.50		[illegible]	[illegible]	99.53	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	20			[illegible]	[illegible]	[illegible]	4		
[illegible]	1.26	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]		
.20	14.50	0.09	0.02	0.17	0.02	0.21	22.40		2.20	21.10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			2	1700	4.9	36	3	

	30	230	-10	80	20		4													
	110	520	10	110	10															
	30	150	-10	150	-10															
	-10	140	100	40	10		5													
	20	110	40	30	-10		10													
	-10	50	-10	60	20		17													
	130	60	10	160	10		4													
	160	30	10	150	-10		-1													
	60	30	-10	120	20		-1													
	160	-10	10	150	10		1													
	50	100	10	130	10		2													
	-10	40	20	130	20		3													
	90	100	30	150	20		4													
	100	200	10	150	10		7													
	80	210	10	120	-10		-1													
	-10	40	10	-10	30		-1													
	40	80	20	120	20		3													
	-10	110	10	50	20		2													
	10	180	-10	80	10		3													
	10	650	20	60	10		3													
	30	220	30	130	10		6													
	19	42	20	72	8	368			106		457			4						
	36	102	18	44	7	150			201		252			11						
	9	53	15	28	7	5			159		214			4						
	27	294	17	53	7	126			168		218			10						
	-2	41	24	174	12	202			40		682			15						
	46	184	8	79	11	465			25		42			4						
	-2	84	19	55	9	79			28		364			4						
	7	177	15	38	5	55			80		174			4						
	68	270	15	172	14	867			14		74			50						
	102	284	17	157	13	1177			16		62			42						
	16	179	23	99	8	195			64		383			4						
	32	542	12	173	15	605			39		69			50						
	28	499	11	148	11	419			44		79			22						
	18	459	20	146	8	729			68		266			27						
	13	160	14	34	8	70			180		161			5						
	28	103	17	40	6	236			154		237			4						
	28	160	16	38	8	160			191		188			4						
	3	118	16	38	7	106			141		220			14						
	216	21	29	174	15	1046			27		139			16						
	54	87	9	111	18	239			5		25			33						
	61	97	12	106	11	616			18		52			26						
	61	140	12	94	13	494			28		76			9						
	34	326	34	76	5	149			140		159			4						
	200	10	20	260	10		2084	23	58	21.70	200	103	10							
	[illegible]	5	5	150	20		280	13	56	13.30	120	61								
	40	20	10	130	20		1524	19	28	13.30	110	66	10	34.3	28	4.87	1.15	0.50	1.63	0.29
10	140	50	30	120	10		4479	18	46	12.70	150	82								
	70	70	60	410	20		56204	22	150	23.00	200	376	10							
10	20	190	20	90	20		31	7	360	10.40	70	120	10	65.8	48	8.05	1.82	0.70	1.06	0.15
	[illegible]	30	40	80	10		93	15	120	51.80	370	36								
10	[illegible]	80	40	100	10		31	14	140	18.60	150	42	10							
10	[illegible]	5	10	130	20		31	15	160	19.00	130	70								
	20	50	20	240	30		62	14	100	14.40	140	210	10							
10	[illegible]	20	5	130	30		8087	18	51	8.80	92	40								
	[illegible]	5	10	110	5		31	13	120	16.8	120	35	10							
10	[illegible]	10	5	160	10		31	20	58	9.2	84	49								
	[illegible]	10	5	100	20		31	19	130	17.4	120	41		20.1	16	2.68	0.72	0.3	1.02	0.16
10	[illegible]	5	10	80	20		31	14	190	20.8	180	63								
	[illegible]	10	5	120	10		3452	11	120	12.6	150	46	20							
	[illegible]	10	20	150	10		31	19	170	11.6	98	59	20							
	[illegible]	5	5	130	5		31	15	71	7.5	72	36								
20	5	10	5	20	40		3701	4	71	2.4	36	1								
20	5	50	5	30	10		31	6	38	4	46	16	20							
	20	5	5	5	10			3	44	2.8	40	9								
	[illegible]	530	5	5	20			2	290	4.8	30	7		2.5	3	0.55	0.29	0.1	0.27	0.04
	20	420	10	5	20			2	1100	5.1	32	1								
	20	330	5	5	10			3	1300	9.2	48	3	10	1.3	3	0.32	0.14	0.1	0.28	0.04
	[illegible]	190	5	20	10			5	940	13.4	74	4								
		5	5	5	5			2	1700	4.9	36	3								
		10	5	5	20			3	2600	5.4	50	6								
		5	5	5	20			2	2900	10	28	2								
		250	10	5	20			2	2400	7.3	38	2								
		120	5	5	20			1	2700	5.2	20	1								
		210	10	5	10			3	2200	7.6	34	3	10							
		150	5	5	10			4	1700	14	66	3	10							

	Sr	Y	Zr	Nb	Ba	Au (ppb)	Ga	Ni	Sc	V	Ce	Ge	La	Nd	Sm	Eu	Tb	Yb	Lu	Mo
	190	5	5	10			1	2500	4.3	22	1	10								
	90	5	5	20			3	2200	3.5	14	1									
	30	5	5	0			2	2500	6.6	26	4	10	0.8	3	0.19	0.11	0.1	0.24	0.03	
	5	20	70	20			9	1100	26.4	160	37									
	10	40	310	50	80															
	80	-10	30	20	360															
	60	10	210	20	1040															
	20	[illegible]	[illegible]	[illegible]			[illegible]	2600	5.4	50	6									

EAST COOR.	NORTH COOR.	MAP SAMPLE #	ACTUAL SAMPLE #	MAP BLOCK	ROCK CODE	ROCK DESCRIPTION	REFERENCE NAME	REFERENCE YEAR	ELEMENTS SiO2	Al2O3	Fe2O3	FeO	MgO	C
.58	52945.20	300	[illegible]											
14.58	52945.20	301	RS-16-291	P	5ad	cb-qtz-chl rock	Brozdowski	1988	55.00	0.79	1.55	2.54	22.70	
14.58	52945.20	302	RS-16-162	P	5ad	cb-qtz-chl rock	Brozdowski	1988	56.40	1.48	1.57	3.01	28.80	
14.58	52945.20	303	RS-16-226	P	5at	carbonate talc rock	Brozdowski	1988	27.90	1.49	1.59	2.81	37.10	
14.58	52945.20	304	RS-26-191	P	5at	carbonate talc rock	Brozdowski	1988	29.00	1.82	1.58	3.85	25.00	1
14.58	52945.20	305	RS-16-477	P	5at	carbonate talc rock	Brozdowski	1988	30.40	0.64	1.54	4.51	29.20	
14.58	52945.20	306	RISO-45	P	5at	carbonate talc rock	Brozdowski	1988	34.50	1.47	1.58	3.36	25.40	1
14.58	52945.20	307	RISO-50	P	5at	carbonate talc rock	Brozdowski	1988	35.80	3.19	1.65	5.97	24.30	

EAST COOR.	NORTH COOR.	MAP SAMPLE #	ACTUAL SAMPLE #	MAP BLOCK	ROCK CODE	ROCK DESCRIPTION	REFERENCE NAME	REFERENCE YEAR	ELEMENTS SiO2	Al2O3	Fe2O3	FeO	MgO	C
14.58	52945.20	308	RISO-51	P	5a	serpentinized peridotite	Brozdowski	1988	12.40	0.36	1.54	5.93	35.20	
14.58	52945.20	309	RS-26-259	P	5a	serpentinized peridotite	Brozdowski	1988	29.40	0.33	1.53	4.89	32.80	
14.58	52945.20	310	RISO-46	P	5a	serpentinized peridotite	Brozdowski	1988	35.40	1.26	1.57	4.50	36.20	
14.58	52945.20	311	RS-16-548	P	5a	serpentinized peridotite	Brozdowski	1988	32.70	10.90	2.30	10.62	27.00	
50.32	53236.92	312	DLP-1-276.5	P	5a	serpentinized peridotite	Brozdowski	1986	31.00	12.10	4.13	7.26	30.20	
50.30	53233.87	313	DLP-1-511.5	B	2c	latite dike	Brozdowski	1986	67.80	13.70	1.60	-0.06	6.21	
50.30	53233.87	314	DLP-1-556	B	2c	latite dike	Brozdowski	1986	52.60	17.50	2.33	3.17	11.50	
50.30	53233.87	315	DLP-1-731	P	5a	ultramafic dike	Brozdowski	1986	31.60	16.10	2.51	0.22	35.30	
76.32	52782.60	316	DL-4	P	5a	serpentinized peridotite	Brozdowski	1986	40.20	2.91	1.69	8.20	31.60	
09.84	63137.40	317	VS77-20	S	2a	rhyolite	Hammond	1976	71.39	13.13	1.74	0.10	0.42	
93.00	57938.89	318	VS77-21	B	6c	tonalite	Hammond	1976	63.61	19.61	1.98	2.12	1.60	
14.58	52945.20	319	1	B	2b■	quartz-sericite-chlorite rock	Creasy	1981	37.70	23.80	11.20	0.00	10.60	
14.58	52945.20	320	2	B	2b■	quartz-sericite-chlorite rock	Creasy	1981	55.40	12.80	1.40	5.50	17.50	
14.58	52945.20	321	3	B	2b■	quartz-sericite-chlorite rock	Creasy	1981	61.30	16.30	0.64	4.60	6.10	
14.58	52945.20	322	4	B	2b■	quartz-sericite-chlorite rock	Creasy	1981	72.00	13.20	3.10	0.24	1.90	
14.58	52945.20	323	5	B	2b■	quartz-sericite-chlorite rock	Rossell	1983	48.39	15.07	10.28	0.00	16.57	
14.58	52945.20	324	6	B	2b■	quartz-sericite-chlorite rock	Rossell	1983	50.05	15.68	8.27	0.00	14.33	
14.58	52945.20	325	7	B	2b■	quartz-sericite-chlorite rock	Rossell	1983	49.57	17.85	7.67	0.00	11.67	
27.44	50610.75	326	HR-5	K	5a	serpentinized peridotite	Rossell	1983	43.20	1.96	0.00	8.99	36.77	
72.86	53010.57	327	HR-191	P	5a	serpentinized peridotite	Rossell	1983	42.55	0.03	0.00	5.67	35.07	
57.86	51824.74	328	HR-202	P	5a	serpentinized peridotite	Rossell	1983	42.18	0.98	0.00	9.69	36.12	
29.83	53417.25	329	HR-197	P	5a	serpentinized peridotite	Rossell	1983	39.88	1.71	0.00	5.58	34.29	
00.95	52514.05	330	HR-51	K	5a	serpentinized peridotite	Rossell	1983	41.88	5.34	0.00	10.00	26.60	
14.31	53365.42	331	HR-40	K	5a	serpentinized peridotite	Rossell	1983	42.03	5.53	0.00	10.59	27.69	
55.89	52214.91	332	HR-148	P	5a	serpentinized peridotite	Rossell	1983	41.10	0.00	0.00	6.33	35.53	
2.74	51406.30	333	HR-113	K	5a	serpentinized peridotite	Rossell	1983	40.21	3.82	0.00	9.48	29.57	
1.18	52219.40	334	HR-208	P	5a	serpentinized peridotite	Rossell	1983	38.30	0.00	0.00	12.21	31.85	
3.73	53417.29	335	HR-232	P	5a	serpentinized peridotite	Rossell	1983	44.46	2.07	0.00	5.43	37.73	
4.58	52945.20	336	HR-54	P	5atd	carb-quartz-chl-talc rk	Rossell	1983	46.21	1.65	1.57	4.94	26.55	
4.58	52945.20	337	HR-55	P	5atd	carb-quartz-chl-talc rk	Rossell	1983	54.32	4.59	1.64	2.83	22.78	
4.58	52945.20	338	HR-57	P	5at	talc carbonatized rock	Rossell	1983	26.83	5.62	1.63	3.28	20.55	
14.58	52945.20	339	HR-59	P	5at	talc carbonatized rock	Rossell	1983	47.86	2.01	1.54	2.39	24.01	
4.58	52945.20	340	HR-60	P	5at	talc carbonatized rock	Rossell	1983	42.04	1.34	1.55	2.66	23.39	
4.58	52945.20	341	HR-62	P	5at	talc carbonatized rock	Rossell	1983	39.77	2.06	1.57	3.58	25.13	
4.58	52945.20	342	HR-63	P	5at	talc carbonatized rock	Rossell	1983	45.56	1.03	1.54	3.46	27.63	
4.58	52945.20	343	HR-64	P	5a	serpentinized peridotite	Rossell	1983	39.30	1.17	1.56	5.02	28.39	
4.58	52945.20	344	HR-66	P	5a	serpentinized peridotite	Rossell	1983	46.12	1.13	1.55	3.46	29.01	
4.58	52945.20	345	HR-67	P	5a	serpentinized peridotite	Rossell	1983	52.74	1.29	1.55	4.06	30.63	
4.58	52945.20	346	HR-216	P	5ad	carb-qtz-chl-talc rock	Rossell	1983	53.99	1.24	1.55	3.50	25.19	
4.58	52945.20	347	HR-100	P	5ad	carb-qtz-chl-talc rock	Rossell	1983	11.91	0.17	1.51	1.14	17.21	
4.58	52945.20	348	HR-99	P	5at	talc-carbonatized rock	Rossell	1983	36.07	3.36	1.59	5.43	23.37	
4.58	52945.20	349	HR-98	P	5at	talc-carbonatized rock	Rossell	1983	37.27	0.39	1.53	5.57	28.66	
.58	52945.20	350	HR-97	P	5at	talc-carbonatized rock	Rossell	1983	40.03	1.04	1.53	2.30	23.34	
.58	52945.20	351	HR-96	P	5at	talc-carbonatized rock	Rossell	1983	40.21	0.13	1.52	5.57	30.21	
.58	52945.20	352	CR-41	P	5at	talc-carbonatized rock	Rossell	1983	48.60	1.19	1.53	4.23	25.86	
.58	52945.20	353	CR-40	P	5at	talc-carbonatized rock	Rossell	1983	46.22	1.48	1.56	4.45	26.74	
.58	52945.20	354	HR-126	P	5atd	carb-qtz-chl-talc rock	Rossell	1983	48.79	4.42	1.60	1.70	13.88	
.58	52945.20	355	CR-46	P	5atd	carb-qtz-chl-talc rock	Rossell	1983	26.40	2.30	1.54	1.55	15.46	
.58	52945.20	356	CR-47	P	5atd	carb-qtz-chl-talc rock	Rossell	1983	50.23	2.47	1.5[illegible]	2.92	23.35	
.58	52945.20	357	HR-122	P	5at	talc-carb rock	Rossell	1983	38.29	1.55	1.55	4.00	23.15	
.58	52945.20	358	HR-119	P	5at	talc-carb rock	Rossell	1983	39.28	0.73	1.54	5.28	32.56	
.58	52945.20	359	HR-118	P	5at	talc-carb rock	Rossell	1983	46.58	1.16	1.55	4.91	30.80	
.58	52945.20	360	HR-117	P	5atd	carb-qtz-chl-talc rock	Rossell	1983	51.45	3.56	1.58	4.01	25.18	
.58	52945.20	361	CR-35A	P	5a	serpentinized peridotite	Rossell	1983	41.44	0.32	1.53	4.45	36.12	
.58	52945.20	362	CR-55	P	5at	talc-carb rock	Rossell	1983	43.33	7.15	1.67	2.52	21.00	
.12	53417.08	363	HR-228	P	5a	chlorite-actinolite schist	Rossell	1983	44.46	14.84	1.89	5.90	18.08	
.58	52945.20	364	HR-89	P	5atd	carb-qtz-chl-talc rock	Rossell	1983	57.11	3.41	1.62	2.74	15.16	
.42	53196.41	365	HR-169	P	5a	serpentinized peridotite	Rossell	1983	42.44	1.00	1.57	5.85	34.89	
.53	52205.85	366	HR-146	P	5a	serpentinized peridotite	Rossell	1983	44.84	0.09	1.52	4.57	31.73	
.58	52945.20	367	EOHR-53	B	2b■	quartz-sericite rock	Shepeck	1985	63.11	18.08	2.24	1.40	2.57	
.58	52945.20	368	COHR-129	B	2b■	quartz-sericite rock	Shepeck	1985	54.75	10.21	2.57	4.09	7.48	
.58	52945.20	369	COHR-127	B	2b■	quartz-sericite rock	Shepeck	1985	57.35	12.08	2.28	2.61	7.37	
.58	52945.20	370	COHR-R15	B	2b■	quartz-sericite rock	Shepeck	1985	64.92	15.99	1.90	0.78	6.50	
.58	52945.20	371	EOHR-14A	B	2b■	quartz-sericite rock	Shepeck	1985	56.91	16.51	2.35	3.55	8.99	
.58	52945.20	372	EOHR-14C	B	2b■	quartz-sericite rock	Shepeck	1985	56.08	17.44	2.32	4.51	8.96	
.58	52945.20	373	COHR-132	B	2b■	quartz-sericite rock	Shepeck	1985	56.83	17.27	1.93	2.27	11.04	
.58	52945.20	374	COHR-10	B	2b■	quartz-sericite rock	Shepeck	1985	62.32	17.21	2.19	2.95	5.61	
.58	52945.20	375	EOHR-752SW	B	2b■	quartz-sericite rock	Shepeck	1985	61.36	18.22	2.16	2.24	4.98	
.58	52945.20	376	EOHR-14D	B	2b■	quartz-sericite rock	Shepeck	1985	54.66	19.59	2.21	[illegible]	7.62	
.58	52945.20	377	COHR-8A	B	2b■	quartz-sericite rock	Shepeck	1985	64.47	15.83	1.95	1.46	8.[illegible]	
.58	52945.20	378	COHR-1070D	B	2b■	quartz-sericite rock	Shepeck	1985	57.40	17.62	2.16	3.24	5.90	
.58	52945.20	379	EOHR-15EL	B	2b■	quartz-sericite rock	Shepeck	1985	63.62	13.27	2.86	[illegible]	7.61	
.58	52945.20	380	COHR-219	B	2b■	quartz-sericite rock	Shepeck	1985	63.62	[illegible]	[illegible]	[illegible]	4.65	
.58	52945.20	381	OMR-15-D	B	2b■	quartz-sericite rock	Shepeck	1985	63.61	[illegible]	[illegible]	[illegible]	4.65	
.58	52945.20	382	OMR-9-BS	B	2b■	quartz-sericite rock	Shepeck	[illegible]	56.44	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	52945.20	383	OMR-15-[illegible]	[illegible]	2b■	quartz-sericite rock	Shepeck	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	384	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	

2.70	0.98	0.13	0.01	0.05	0.01	0.04	14.80		[illegible]	[illegible]	[illegible]															
8.80	0.67	0.07	0.01	0.07	0.01	0.02	6.00		3.70	1.30	98.11	1080	40	10	5	5	20			3	2600	5.4	30	0		
7.10	0.30	0.10	0.01	0.09	0.01	0.15	28.40		2.30	25.10	99.95	750	10	5	5	5	20			2	2900	10	28	2		
5.00	14.10	0.10	0.01	0.08	0.02	0.11	23.80		2.80	21.00	99.47	1660	10	250	10	5	20			2	2400	7.3	38	2		
9.20	9.37	0.09	0.01	0.04	0.01	0.11	23.80		2.20	22.50	99.72	2480	10	120	5	5	20			1	2700	5.2	20	1		
5.40	11.80	0.08	0.01	0.08	0.02	0.18	20.30		3.00	18.20	98.78	2010	5	-210	10	5	10			3	2200	7.6	34	3	10	
4.30	9.48	0.09	0.01	0.15	0.02	0.18	17.80		3.70	14.20	98.64	2450	10	150	5	5	10			4	1700	14	66	3	10	

MgO	CaO	Na2O	K2O	TiO2	P2O5	MnO	LOI	H2O-	H2O+	CO2	SUM	Cr	Rb	Sr	Y	Zr	Nb	Ba	Au (ppb)	Ga	Ni	Sc	V	Ce	Ge	
35.20	6.61	0.09	0.02	0.04	0.02	0.17	37.00		1.70	35.90	99.38	3200	5	190	5	5	10			1	2500	4.3	22	1	10	
32.80	4.84	0.06	0.01	0.03	0.02	0.12	25.50		1.80	23.20	99.53	2740	10	90	5	5	20			3	2200	3.5	14	1		
36.20	1.26	0.12	0.02	0.07	0.02	0.12	18.70		6.10	11.40	99.24	1840	5	30	5	5	0			2	2500	6.6	26	4	10	
27.00	0.78	0.10	0.01	0.80	0.12	0.04	11.90		8.00	1.10	97.27	620	5	5	20	70	20			9	1100	26.4	160	37		
30.20	0.53	0.01	0.03	2.63	0.37	0.19	10.90				99.35	-68	10	10	40	310	50	80								
6.21	0.10	6.16	2.17	0.10	0.02	0.03	1.62				99.45	68	140	80	-10	30	20	360								
11.50	0.28	0.22	5.76	0.83	0.21	0.09	5.23				99.72	-68	120	80	10	210	20	1940								
35.30	0.31	0.10	0.15	1.01	0.23	0.42	12.20				100.15	-68	10	-10	30	240	-10	150								
31.60	1.97	0.02	0.02	0.19	0.03	0.09	12.00				98.92	3762	20	-10	-10	-10	20	120								
0.42	0.51	2.94	2.96	0.24			4.87				98.30		71	309				547								
1.60	3.18	3.89	2.21	0.48			1.22				99.90		65	92				589								
10.60	0.40	0.52	5.70	1.10	0.29	0.03					91.34															
17.50	0.60	0.02	0.01	0.59	0.17	0.03				0.50	94.52															
6.10	0.38	4.70	1.30	0.64	0.18	0.11				0.05	96.30															
1.90	0.26	0.07	4.20	0.48	0.02	0.01				0.20	95.68															
16.57	0.60	0.18	3.01	1.01	0.08	0.05				0.00	95.24	171	68	19	16	96	17				255	19	131	56		[illegible]
14.33	1.23	0.19	3.55	0.98	0.07	0.05				0.00	94.40	175	79	26	18	101	17				191	20	124	53		[illegible]
11.67	0.35	0.20	4.54	0.77	0.17	0.03				0.00	92.82	48	114	20	18	129	21				178	13	94	42		[illegible]
36.77	0.27	0.03	0.00	0.11	0.01				9.70	0.00	101.04	5172										11	85			
35.07	2.30	0.03	0.00	0.02	0.02				6.70	7.80	100.19	1988							1			6	39			
36.12	1.48	0.03	0.00	0.05	0.02				6.20	2.15	98.90	4667							4			7	52			
34.29	4.36	0.03	0.01	0.07	0.02				8.20	5.08	99.23	1582										12	49			
26.60	2.08	0.04	0.02	0.27	0.03				6.80	6.06	99.12	2918							3			19	126			
27.69	1.89	0.06	0.02	0.24	0.03				7.20	3.75	99.03	3343										19	123			
35.53	4.01	0.03	0.00	0.01	0.03				9.90	2.12	99.06	2274										8	17			
29.57	1.60	0.05	0.01	0.21	0.02				7.50	0.00	92.47	3423										15	82			
31.85	3.14	0.03	0.00	0.01	0.02				6.50	6.87	98.93	3940										7	43			
37.73	0.35	0.04	0.00	0.06	0.01				6.50	1.22	97.87	2163							4			6	70			
26.55	1.98	0.04	0.01	0.07	0.02				2.50	12.36	97.90	1558							4		2901	8	50			
22.78	7.25	0.05	0.01	0.14	0.05				1.40	3.96	99.02	1443									1844	14	56			
20.55	19.02	0.05	0.01	0.13	0.06				2.50	16.11	95.79	1275							10		1078	14	37			
24.01	11.80	0.03	0.01	0.04	0.07				0.80	8.68	99.24	1029									1899	17	22			
23.39	14.85	0.04	0.01	0.05	0.09				1.00	11.35	98.37	1255							-6		1736	19	30			
25.13	10.67	0.03	0.01	0.07	0.05				4.30	13.47	100.71	1305							2		2264	17	59			
27.63	8.29	0.05	0.01	0.04	0.04				1.40	9.79	98.84	1805							2		2303	14	37			
28.39	4.81	0.05	0.01	0.06	0.03				3.80	13.47	97.67	1603							1		2494	11	21			
29.01	5.09	0.04	0.01	0.05	0.03				5.10	8.25	99.84	1478									2466	12	27			
30.63	1.41	0.04	0.01	0.05	0.01				5.00	4.11	100.90	2040									2816	9	66			
25.19	6.20	0.05	0.00	0.05	0.03					4.88	96.68	1482									2089	11	59			
17.21	27.71	0.10	0.02	0.01	0.14					37.84	97.76	139							19		187	23	21			
23.37	9.58	0.06	0.02	0.09	0.05					17.45	97.07	1864									3238	16	82			
28.66	0.40	0.05	0.01	0.03	0.01					23.04	96.96	2534									3551	6	9			
23.34	13.49	0.06	0.01	0.03	0.06					15.12	97.01	1686									2701	15	22			
30.21	0.33	0.06	0.00	0.02	0.01					17.21	95.27	2666							4		3406	8	21			
25.86	3.10	0.04	0.01	0.03	0.03					11.54	96.16	1534									3064	8	28			
26.74	5.77	0.05	0.00	0.06	0.04					13.93	100.30	2122									2905	12	36			
13.88	15.52	0.05	0.01	0.10	0.07				2.10	11.70	99.93										1870	22	69			
15.46	26.00	0.04	0.10	0.04	0.16				1.50	15.72	90.81										1410	26	16			
23.35	9.99	0.07	0.01	0.09	0.06				1.10	6.96	98.84										3164	17	33			
23.15	10.48	0.05	0.01	0.05	0.05				2.20	19.16	100.54					15					2054	15	31			
32.56	0.61	0.05	0.01	0.04	0.02				4.00	16.02	100.14										3312	6	39			
30.80	0.25	0.05	0.01	0.05	0.01				2.70	10.45	98.52										3414	6	35			
25.18	4.63	0.05	0.01	0.08	0.04				1.80	7.14	99.53								7		21					
36.12	3.13	0.03	0.00	0.03	0.02				7.60	3.76	98.43	3794									2412	10	25			
21.00	12.70	0.06	0.01	0.17	0.08				1.30	9.06	99.05	1364							2		1032	22	91			
18.08	6.81	0.12	0.03	0.39	0.06				4.20	1.37	98.15	2534				37					1096	26	185			
15.16	14.14	0.09	0.00	0.12	0.05				2.50	2.24	93.18	1197									1268	16	76			
34.89	1.25	0.03	0.01	0.07	0.01						87.[illegible]	2736							2		313[illegible]	8	35			
31.73	0.30	0.03	0.01	0.02	0.01				6.50	8.54	98.16	1873									3466	4	24			
2.57	0.26	0.22	6.08	0.74		0.01					94.71	56	199	21	35	152	-10	489			41	10	87	71		
7.48	4.64	0.22	4.29	1.07		0.09					89.41	667	134	93	48	124	-10	382			114	22	127	76		
7.37	2.72	0.22	4.78	0.78		0.06					90.25	111	146	46	33	155	-10	382			67	14	92	66		
6.50	1.20	0.14	4.05	0.40		0.03					[illegible]	37	112	24	9	130	-10	254			208	6	51	[illegible]		
8.99	2.77	0.14	3.56	0.85		[illegible]					[illegible]	127	115	24	25	156	-10	443			81	14	96	83		
8.96	2.90	0.14	3.52	0.82		[illegible]					[illegible]	179	114	27	29	139	-10	433			85	15	97	76		
11.04	[illegible]	0.13	3.64	0.43		0.02					93.79	42	102	13	15	130	[illegible]	277			73	6	55	[illegible]		
5.61	1.32	0.15	4.65	0.69		0.05					97.14	62	150	23	33	140	[illegible]	384			46	[illegible]	77	57		
4.98	1.00	0.16	[illegible]	0.66		0.04					[illegible]	48	170	19	33	155	[illegible]	438			[illegible]	[illegible]	75	[illegible]		
7.62	2.60	0.22	[illegible]	[illegible]		[illegible]					95.15	39	128	46	33	154	[illegible]	419			38	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	0.15	3.65	[illegible]		0.02					[illegible]	39	[illegible]	[illegible]	[illegible]	14	[illegible]	[illegible]			[illegible]	6	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	3.45	0.66		0.04					94.95	55	[illegible]	[illegible]	24	136	[illegible]	[illegible]			43	[illegible]	63	[illegible]		
[illegible]	[illegible]	[illegible]	2.24	[illegible]		0.06					[illegible]	245	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	408			104	35	[illegible]	[illegible]		
4.65	[illegible]	[illegible]	5.12	[illegible]		[illegible]					[illegible]	39	144	45	[illegible]	139	[illegible]	384			55	6	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]					[illegible]	[illegible]	94	[illegible]	[illegible]	[illegible]		[illegible]			[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]					[illegible]	44	[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	58	4		

	Sr	Y	Zr	Nb	Ba	Au (ppb)	Ga	Ni	Sc	V	Ce	Ge	La	Nd	Sm	Eu	Tb	Yb	Lu	Mo
	3	3	5	20			2	2900	10	28	2									
10	250	10	5	20			2	2400	7.3	38	2									
10	120	5	5	20			1	2700	5.2	20	1									
5	210	10	5	10			3	2200	7.6	34	3	10								
10	150	5	5	10			4	1700	14	66	3	10								
10																				

Ge	Sr	Y	Zr	Nb	Ba	Au (ppb)	Ga	Ni	Sc	V	Ce	Ge	La	Nd	Sm	Eu	Tb	Yb	Lu	Mo
	190	5	5	10			1	2500	4.3	22	1	10								
10	90	5	5	20			3	2200	3.5	14	1									
	30	5	5	0			2	2500	6.6	26	4	10	0.8	3	0.19	0.11	0.1	0.24	0.03	
10	5	20	70	20			9	1100	26.4	160	37									
	10	40	310	50	80															
	80	-10	30	20	360															
	80	10	210	20	1940															
	-10	30	240	-10	150															
	-10	-10	-10	20	120															
	309				547															
	92				589															
	19	16	96	17				255	19	131	56		15.0							
15	26	18	101	17				191	20	124	53		12.0							
12	20	18	129	21				178	13	94	42		12.0							
12									11	85										
						1			6	39										
						4			7	52										
									12	49										
						3			19	126										
									19	123										
									8	17										
									15	82										
									7	43										
						4			6	70										
						4		2901	8	50										
								1844	14	56										
						10		1078	14	37										
								1899	17	22										
						-6		1736	19	30										
						2		2264	17	59										
						2		2303	14	37										
						1		2494	11	21										
								2466	12	27										
								2816	9	66										
								2089	11	59										
						19		187	23	21										
								3238	16	82										
								3551	6	9										
								2701	15	22										
						4		3406	8	21										
								3064	8	28										
								2905	12	36										
								1870	22	69										
								1410	26	16										
								3164	17	33										
			15					2054	15	31										
								3312	6	39										
								3414	6	35										
						7		21												
								2412	10	25										
						2		1032	22	91										
			37					1096	26	185										
								1268	18	76										
						2		3132	8	35										
								3468	4	24										
	21	35	152	-10	489			41	10	87	71		32.0							
	93	48	124	-10	382			114	22	127	78		28.0							
	46	33	155	-10	382			67	14	92	66		26.0							
	24	9	130	-10	254			208	6	51	-25		12.0							
	[illegible]	25	156	-10	443			81	14	96	83		30.0							
	27	29	139	-10	433			85	15	97	76		25.0							
	13	15	130	-10	277			73	6	55	-25		21.0							
	23	33	140	-10	384			46	11	77	59		32.0							
	29	33	150	-10	438			26	10	75	61		27.0							
	46	32	154	-10	429			38	12	79	58		26.0							
	12	6	141	-10	252			78	6	56	16		14.0							
	[illegible]	24	136	-10	327			43	10	83	52		24.0							
	23	27	102	-10	408			104	35	184	75		-10.0							
	46	16	139	-10	386			55	6	63	30		11.0							
	45	25	121	17	348			185	25	143	66		31.0							
	15	23	126	21	322			31	9	88	42		21.0							
	[illegible]	12	134	[illegible]	256			43	[illegible]	67	-25		13.0							
			25	[illegible]	[illegible]															

EAST COOR.	NORTH COOR.	MAP SAMPLE #	ACTUAL SAMPLE #	MAP BLOCK	ROCK CODE	ROCK DESCRIPTION	REFERENCE NAME	REFERENCE YEAR	SiO2	Al2O3	Fe2O3	FeO	MgO	CaO
[illegible]	[illegible]	360	HR-117	P	5ad	carb-qtz-chl-talc rock	Rossell	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3.4.58	52945.20	361	CR-35A	P	5a	serpentinized peridotite	Rossell	1983	41.44	0.32	1.53	4.45	36.12	3.13
3.4.58	52945.20	362	CR-55	P	5at	talc-carb rock	Rossell	1983	43.33	7.15	1.67	2.52	21.00	12.70
321.12	53417.08	363	HR-228	P	5a	chlorite-actinolite schist	Rossell	1983	44.46	14.84	1.89	5.90	18.08	6.81
314.58	52945.20	364	HR-89	P	5a d	carb-qtz-chl-talc rock	Rossell	1983	57.11	3.41	1.62	2.74	15.16	14.14
289.42	53196.41	365	HR-169	P	5a	serpentinized peridotite	Rossell	1983	42.44	1.00	1.57	5.85	34.89	1.25
460.53	52205.85	366	HR-146	P	5a	serpentinized peridotite	Rossell	1983	44.84	0.09	1.52	4.57	31.73	0.30
314.58	52945.20	367	EOHR-53	B	2bm	quartz-sericite rock	Shepeck	1985	63.11	18.08	2.24	1.40	2.57	0.26
314.58	52945.20	368	COHR-129	B	2bm	quartz-sericite rock	Shepeck	1985	54.75	10.21	2.57	4.09	7.48	4.64
314.58	52945.20	369	COHR-127	B	2bm	quartz-sericite rock	Shepeck	1985	57.35	12.08	2.28	2.61	7.37	2.72
314.58	52945.20	370	COHR-R15	B	2bm	quartz-sericite rock	Shepeck	1985	64.92	15.99	1.90	0.78	6.50	1.20
314.58	52945.20	371	EOHR-14A	B	2bm	quartz-sericite rock	Shepeck	1985	56.91	16.51	2.35	3.55	8.99	2.77
314.58	52945.20	372	EOHR-14C	B	2bm	quartz-sericite rock	Shepeck	1985	56.08	17.44	2.32	4.51	8.96	2.90
314.58	52945.20	373	COHR-132	B	2bm	quartz-sericite rock	Shepeck	1985	56.83	17.27	1.93	2.27	11.04	0.23
314.58	52945.20	374	COHR-10	B	2bm	quartz-sericite rock	Shepeck	1985	62.32	17.21	2.19	2.95	5.61	1.32
314.58	52945.20	375	EOHR-752SW	B	2bm	quartz-sericite rock	Shepeck	1985	61.36	18.22	2.16	2.24	4.98	1.00
.4.58	52945.20	376	EOHR-14D	B	2bm	quartz-sericite rock	Shepeck	1985	54.66	19.59	2.21	3.16	7.62	2.60
.4.58	52945.20	377	COHR-8A	B	2bm	quartz-sericite rock	Shepeck	1985	64.47	15.83	1.95	1.46	8.77	0.16
.4.58	52945.20	378	COHR-1070D	B	2bm	quartz-sericite rock	Shepeck	1985	57.40	17.62	2.16	3.24	8.90	[illegible]
.4.58	52945.20	379	EOHR-15EL	B	2bm	quartz-sericite rock	Shepeck	1985	63.62	13.27	2.86	5.61	7.61	[illegible]
314.58	52945.20	380	COHR-219	B	2bm	quartz-sericite rock	Shepeck	1985	63.6[illegible]	17.56	1.97	[illegible]	4.65	2.00
314.58	52945.20	381	OHR-15-D	B	2bm	quartz-sericite rock	Shepeck	1985	56.44	[illegible]	2.65	[illegible]	[illegible]	1.96
314.58	52945.20	382	OHR-9-BS	B	2bm	quartz-sericite rock	Shepeck	1985	62.83	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	52945.20	383	OHR-15-BSC	B	2bm	quartz-sericite rock	Shepeck	1985	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	52945.20	384	OHR-15-A	B	2bm	quartz-sericite rock	Shepeck	1985	67.25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
.4.58	52945.20	385	OHR-15-BSB	B	2bm	quartz-sericite rock	Shepeck	1985	69.66	16.73	1.92	0.64	1.64	0.16
.4.58	52945.20	386	OHR-9-BS	B	2bm	quartz-sericite rock	Shepeck	1985	56.67	16.30	2.19	2.59	6.95	0.34
.4.58	52945.20	387	CL-9-AU	B	2bm	quartz-sericite rock	Shepeck	1985	65.52	15.06	1.99	2.14	7.28	0.15
.4.58	52945.20	388	WOHR-78	B	2bm	quartz-sericite rock	Shepeck	1985	58.52	12.01	2.15	3.86	9.72	1.19
.4.58	52945.20	389	EOHR-148	B	2bm	quartz-sericite rock	Shepeck	1985	55.20	17.80	2.28	3.37	7.35	2.80
.4.58	52945.20	390	EOHR-H1	B	2bm	quartz-sericite rock	Shepeck	1985	59.81	16.78	2.20	2.83	8.70	0.95
.4.58	52945.20	391	EOHR-C1	B	2bm	quartz-sericite rock	Shepeck	1985	66.34	16.21	2.20	1.48	3.34	1.13
.4.58	52945.20	392	BS1	B	2bm	quartz-sericite rock	Shepeck	1985	58.28	13.24	2.34	3.67	4.96	3.50
.4.58	52945.20	393	COHR-133	B	2bm	quartz-sericite-chlorite rock	Shepeck	1985	45.18	5.70	1.72	4.82	14.97	15.09
.4.58	52945.20	394	COHR-88	B	2bm	quartz-sericite-chlorite rock	Shepeck	1985	43.57	7.61	1.87	8.17	14.54	12.60
.4.58	52945.20	395	WOHR-86	B	2bm	quartz-sericite-chlorite rock	Shepeck	1985	53.66	14.28	2.25	7.37	10.54	2.57
.4.58	52945.20	396	WOHR-69	B	2bm	quartz-sericite-chlorite rock	Shepeck	1985	50.73	18.49	2.32	5.70	11.91	0.55
.4.58	52945.20	397	WOHR-79	B	2bm	quartz-sericite-chlorite rock	Shepeck	1985	50.22	13.31	2.38	6.76	17.73	1.03
.4.58	52945.20	398	COHR-218	B	2bm	quartz-sericite-chlorite rock	Shepeck	1985	52.37	18.63	2.23	4.46	13.48	0.33
.4.58	52945.20	399	COHR-128	B	2bm	quartz-sericite-chlorite rock	Shepeck	1985	50.69	12.49	2.58	11.12	13.27	3.35
.4.58	52945.20	400	COHR-7	B	2bm	quartz-sericite-chlorite rock	Shepeck	1985	49.57	17.85	2.27	4.86	11.67	0.35
.4.58	52945.20	401	COHR-5	B	2bm	quartz-sericite-chlorite rock	Shepeck	1985	48.39	15.07	2.51	6.99	16.57	0.60
.4.58	52945.20	402	COHR-6	B	2bm	quartz-sericite-chlorite rock	Shepeck	1985	50.05	15.68	2.48	5.21	14.33	1.23
.4.58	52945.20	403	COHR-222	B	2bm	quartz-sericite-chlorite rock	Shepeck	1985	39.79	25.28	2.79	7.83	11.79	0.25
.4.58	52945.20	404	COHR-125	B	2bm	quartz-sericite-chlorite rock	Shepeck	1985	58.08	15.23	1.94	3.98	11.94	0.36
.4.58	52945.20	405	EOHR-54	B	2bm	quartz-sericite-chlorite rock	Shepeck	1985	53.12	11.48	2.29	5.26	[illegible]	0.65
.4.58	52945.20	406	COHR-223	B	2bm	quartz-sericite-chlorite rock	Shepeck	1985	50.92	14.33	2.39	3.85	11.49	[illegible]
.4.58	52945.20	407	COHR-134	B	2bm	quartz-sericite-chlorite rock	Shepeck	1985	58.42	17.22	2.09	4.80	14.44	0.27
.4.58	52945.20	408	WOHR-86A	B	2bm	quartz-sericite-chlorite rock	Shepeck	1985	44.65	13.40	2.23	6.45	17.85	2.11
.4.58	52945.20	409	WOHR-69A	B	2bm	quartz-sericite-chlorite rock	Shepeck	1985	46.71	6.80	1.94	5.82	15.62	11.60
.4.58	52945.20	410	CL-15	B	2bm	chlorite-quartz rock	Shepeck	1985	35.31	16.89	3.04	12.22	18.12	0.44
.4.58	52945.20	411	ECL-56	B	2bm	chlorite-quartz rock	Shepeck	1985	58.57	9.65	2.23	6.86	16.78	0.26
.4.58	52945.20	412	CCL-87	B	2bm	chlorite-quartz rock	Shepeck	1985	33.04	18.33	2.62	12.85	20.25	0.63
.4.58	52945.20	413	COHR-123	B	2bm	chlorite-quartz rock	Shepeck	1985	33.08	15.45	2.46	11.56	25.29	0.29
.4.58	52945.20	414	WCL-64	B	2bm	chlorite-quartz rock	Shepeck	1985	34.81	13.05	2.29	13.81	25.56	0.58
.4.58	52945.20	415	CCL-N15	B	2bm	chlorite-quartz rock	Shepeck	1985	32.29	14.89	2.85	16.84	20.31	0.87
.58	52945.20	416	EOHR-752-BW	B	2bm	chlorite-quartz rock	Shepeck	1985	57.07	11.08	2.34	5.50	17.59	0.60
.58	52945.20	417	WCL-220	B	2bm	chlorite-quartz rock	Shepeck	1985	33.83	16.03	2.51	13.15	22.23	0.30
.58	52945.20	418	CCL-121	B	2bm	chlorite-quartz rock	Shepeck	1985	32.98	15.69	2.91	15.75	20.67	0.84
.58	52945.20	419	WCQBB-74	P	5ad	carbonate-quartz-chlorite rock	Shepeck	1985	39.04	4.19	1.66	5.34	18.29	19.64
.58	52945.20	420	WCQCB-83	P	5ad	carbonate-quartz-chlorite rock	Shepeck	1985	59.16	4.89	1.69	5.94	13.21	8.38
.58	52945.20	421	WCQCB-15	P	5ad	carbonate-quartz-chlorite rock	Shepeck	1985	76.06	8.41	1.70	1.33	12.63	[illegible]
[illegible]	52945.20	422	WCQCB-81	P	5ad	carbonate-quartz-chlorite rock	Shepeck	1985	34.86	1.03	1.75	9.55	30.39	10.47
[illegible]	52945.20	423	WCQCB-80	P	5ad	carbonate-quartz-chlorite rock	Shepeck	1985	36.94	1.24	1.51	2.76	15.76	27.81
[illegible]	52945.20	424	WCQCB-70	P	5ad	carbonate-quartz-chlorite rock	Shepeck	1985	46.14	12.32	2.13	9.79	26.27	0.50
[illegible]	52945.20	425	WCQCB-135	P	5ad	carbonate-quartz-chlorite rock	Shepeck	1985	52.17	2.80	1.57	4.98	30.34	7.94
[illegible]	52945.20	426	WCQCB-73	P	5ad	carbonate-quartz-chlorite rock	Shepeck	1985	31.73	2.40	1.57	3.73	17.41	29.30
[illegible]	52945.20	427	WCQCB-89	P	5ad	carbonate-quartz-chlorite rock	Shepeck	1985	57.44	3.60	1.62	3.59	13.23	15.36
		428	DK-3		7m	mafic gneiss	Snider	1977	46.90	11.90	3.30	12.69	4.60	8.50
		429	DK-7		7m	mafic gneiss	Snider	1977	45.20	11.90	1.80	11.60	5.60	11.23
[illegible]	52945.20	430	RS-17-221	P	5a	peridotite	Brozdowski	1987	33.40	0.66	7.85		38.90	0.23
[illegible]	52945.20	431	RS-15-195	P	5a	peridotite	Brozdowski	1987	42.10	0.45	6.88		38.00	0.28
[illegible]	52945.20	432	RS-8-389	P	5a	peridotite	Brozdowski	1987	33.80	0.46	9.10		35.70	4.06
[illegible]	52945.20	433	RD-26-17	P	1a	basalt	Brozdowski	1987	47.00	12.70	15.00		9.73	3.49
	53382.29	434	MSL-28	B	2b	dacite xl tuff	Brozdowski	1987	65.70	14.70	5.35		3.53	1.34
	53329.05	435	MSL-37	B	2b	dacite xl tuff	Brozdowski	1987	74.80	14.00	1.47		0.61	0.51
	52868.37	436	SLU-2-121	B	2b	dacite xl tuff	Brozdowski	1987	62.40	16.00	5.13		4.60	0.65
	52936.31	437	SLU-3-373	B	2a	dacite flow	Brozdowski	1987	54.70	15.20	7.54		5.46	5.19
	52975.32	438	SLU-4-213	B	2c	dacite feldspar porphyry	Brozdowski	1987	64.50	16.00	4.95		3.27	0.72
	52966.57	439	SLU-3-168	B	2b	dacite tuff	Brozdowski	1987	66.00	15.30	6.28		3.69	2.98

2	3.13	0.03	0.00	0.03	0.02				7.60	3.76	98.43	3794									2412	10	25		
00	12.70	0.06	0.01	0.17	0.08				1.30	9.06	99.05	1364							2		1032	22	91		
08	6.81	0.12	0.03	0.39	0.06				4.20	1.37	98.15	2534				37					1096	26	185		
6	14.14	0.09	0.00	0.12	0.05				2.50	2.24	99.18	1197									1268	18	76		
09	1.25	0.03	0.01	0.07	0.01						87.12	2736							2		3132	8	35		
3	0.30	0.03	0.01	0.02	0.01				6.50	8.54	98.16	1873									3468	4	24		
7	0.26	0.22	6.08	0.74		0.01					94.71	56	199	21	35	152	-10	489			41	10	87	71	
8	4.64	0.22	4.29	1.07		0.09					89.41	667	134	93	48	124	-10	382			114	22	127	78	
7	2.72	0.22	4.78	0.78		0.06					90.25	111	146	46	33	155	-10	382			67	14	92	66	
0	1.20	0.14	4.05	0.40		0.03					95.91	37	112	24	9	130	-10	254			208	6	51	-25	
9	2.77	0.14	3.56	0.85		0.10					95.73	127	115	24	25	156	-10	443			81	14	96	83	
6	2.90	0.14	3.52	0.82		0.10					96.79	179	114	27	29	139	-10	433			85	15	97	76	
4	0.23	0.13	3.64	0.43		0.02					93.79	42	102	13	15	130	-10	277			73	6	55	-25	
1	1.32	0.15	4.65	0.69		0.05					97.14	62	150	23	33	140	-10	384			46	11	77	59	
8	1.00	0.16	5.21	0.66		0.04					96.03	48	170	29	33	150	-10	438			28	10	75	61	
2	2.60	0.22	4.3.	0.71		0.07					95.15	39	128	46	32	154	-10	429			38	12	79	56	
7	0.16	0.15	3.65	0.45		0.02					96.91	39	112	12	6	141	-10	252			78	6	56	16	
0	0.82	0.16	3.95	0.66		0.04					94.95	55	121	17	24	136	-10	327			43	10	83	52	
1	0.66	0.11	2.24	1.36		0.06					97.60	240	79	23	27	102	-10	408			104	35	184	75	
5	2.06	0.18	5.12	0.47		0.04					96.30	39	144	46	16	139	-10	386			55	6	63	30	
7	1.96	[illegible]	3.45	[illegible]		0.06					92.94	767	94	45	25	121	17	348			185	25	143	66	
	[illegible]	0.22	4.82	0.69		0.02					94.76	44	145	15	23	126	21	322			31	9	88	42	
	[illegible]	[illegible]	[illegible]	0.54		[illegible]					94.26	37	155	-2	12	134	[illegible]	256			43	7	67	-25	
	[illegible]	0.22	[illegible]	0.45		[illegible]					93.92	52	147	-2	[illegible]	125	[illegible]	232			120	6	90	-25	

	CaO	Na2O	K2O	TiO2	P2O5	MnO	LOI	H2O-	H2O+	CO2	SUM	Cr	Rb	Sr	Y	Zr	Nb	Ba	Au (ppb)	Ga	Ni	Sc	V	Ce	Ge
4	0.16	0.23	5.19	0.42		0.01					96.60	43	146	-2	11	115	22	228			31	4	61	-25	
95	0.34	0.21	3.93	0.69		0.03					89.90	52	124	12	13	140	23	236			120	11	90	41	
28	0.15	0.20	3.30	0.49		0.02					96.15	41	91	-2	8	108	23	245			17	5	90	-25	
72	1.19	0.20	4.31	0.65		0.04					92.65	54	131	21	30	140	-10	399			50	10	86	61	
55	2.80	0.17	3.73	0.78		0.08					93.56	156	113	26	26	142	-10	440			80	13	88	79	
70	0.95	0.15	4.56	0.70		0.04					96.72	97	164	23	30	141	10	382			76	9	79	55	
54	1.13	0.16	4.27	0.70		0.04					95.87	140	130	28	36	147	10	401			65	11	86	55	1
96	3.50	0.21	4.46	0.84		0.07					91.57	63	101	61	39	131	-10	380			56	18	111	69	2
97	15.09	0.12	0.02	0.22		0.23					88.07	1908	11	105	12	32	10	77			1432	21	53	-25	-1
64	12.60	0.11	0.02	0.37		0.18					89.04	3122	10	94	13	35	-10	105			1563	25	77	-25	-1
64	2.57	0.12	3.55	0.75		0.09					95.18	272	110	39	32	70	-10	346			138	17	97	49	1
91	0.55	0.13	4.57	0.82		0.04					95.26	362	141	17	34	64	-10	456			151	20	120	67	2
73	1.03	0.02	0.69	0.88		0.05					93.07	154	27	33	26	235	20	547			151	13	97	199	12
68	0.33	0.16	3.89	0.73		0.03					96.31	55	107	19	34	96	-10	449			160	12	100	68	2
27	3.35	0.13	1.94	1.08		0.12					93.77	269	64	26	39	90	13	251			150	42	211	46	-1
67	0.35	0.20	4.54	0.77		0.03					92.11	48	114	20	18	129	21	-10			178	13	94	42	
67	0.60	0.18	3.01	1.01		0.05					94.38	171	68	19	16	96	17	-10			255	19	131	56	
63	1.23	0.19	3.55	0.98		0.05					93.75	175	79	26	18	101	17	-10			191	20	124	53	
79	0.25	0.17	6.04	1.29		0.03					95.26	442	183	24	58	176	-10	504			271	29	180	122	3
04	0.36	0.12	2.46	0.44		0.06					94.61	41	78	-2	18	129	109	204			82	6	57	-25	
7.	0.65	0.04	0.02	0.79		0.06					92.65	119	6	37	16	218	23	490			223	11	88	180	11
9	7.66	0.12	2.87	0.89		0.15					94.67	793	87	117	32	113	10	266			137	27	110	56	2
64	0.27	0.12	2.32	0.59		0.03					100.30	77	69	12	13	130	7	330			147	9	73	26	
55	2.11	0.10	3.67	0.73		0.05					91.24	327	78	30	31	87	-10	423			278	24	101	59	2
62	11.60	0.10	3.11	0.44		0.08					92.22	341	36	65	21	72	-10	242			289	23	79	-25	-1
12	0.44	0.17	1.74	1.54		0.10					89.48	1806	58	23	30	210	22	665			486	35	241	197	13
78	0.26	0.06	0.02	0.73		0.08					95.24	470	9	15	14	102	19	238			372	20	98	47	2
25	0.63	0.09	1.72	1.12		0.09					90.77	50	62	30	38	243	13	443			332	18	175	133	4
29	0.29	0.07	0.02	0.96		0.13					89.31	356	9	15	23	166	16	236			425	19	144	56	
66	0.58	0.07	0.02	0.79		0.05					91.03	391	10	27	34	157	19	269			1952	20	136	72	31
31	0.87	0.05	0.02	1.35		0.11					89.56	1136	10	74	29	178	30	502			561	40	216	186	
69	0.60	0.06	0.07	0.84		0.05					95.20	120	8	38	24	233	22	463			163	11	86	165	15
23	0.30	0.06	0.02	1.01		0.10					89.24	370	7	20	27	160	18	276			480	19	150	70	21
67	0.84	0.07	0.02	1.41		0.10					90.44	750	10	28	27	165	29	561			571	23	166	128	84
29	19.64	0.12	0.02	0.16		0.19					88.65	1697	11	18.	13	34	-10	69			2252	21	40	-25	
21	8.38	0.09	0.02	0.19		0.12					93.69	1710	11	100	12	28	-10	75			1300	14	46	-25	
63	0.10	0.22	0.54	0.20		0.01					101.20	65	19	11	-2	50	13	112			52	3	45	-25	
59	10.47	0.09	0.02	0.25		0.25					88.66	3169	12	113	10	21	8	63			3112	12	18	-25	
76	27.81	0.09	0.02	0.01		0.27					86.41	2055	14	199	13	25	-5	51			1682	19	17	-25	
27	0.50	0.07	0.02	0.63		0.03					97.90	221	13	14	15	44	11	195			242	19	113	-25	
54	7.94	0.09	0.02	0.07		0.12					100.10	1726	12	94	9	22	10	67			2550	14	36	-25	
1	29.30	0.12	0.02	0.07		0.13					86.48	1475	14	340	9	41	5	54			1496	22	26	-25	
73	15.36	0.08	0.02	0.12		0.18					95.24	1452	11	163	8	31	9	65			1403	17	33	38	
60	8.50	2.40	0.76	3.70	0.17	0.27	0.10		-0.01	-0.10	95.20														
60	11.20	0.67	1.90	1.80	0.07	0.30	0.70		-0.20	-0.10	92.74														
0	0.23	-0.01	0.0.	0.06	0.01	0..7	18.60			9.50	100.40			-10	-10		10	20		-1	2400	5	100	2	
0	0.28	-0.01	0.02	0.35	0.01	0.05	11.70			0.66	100.20			-10	-10		10	10		-1	2700	5	100	6	
0	4.06	-0.01	0.01	0.05	0.01	0.13	15.80			5.90	100.00			-10	-10		20	20		-1	2800	5	130	4	
3	3.49	0.95	0.62	1.83	0.23	0.14	8.23			4.80	100.00			40	20		20	180		13	91	42	340	52	
3	1.34	5.67	0.74	0.66	0.16	0.10	2.23			0.10	100.30			190	20		30	190		13	20	12	74	41	
1	0.51	5.06	2.48	0.18	0.05	0.02	0.85			0.01	100.10			120	20		20	600		15	8	2	13	20	
0	0.65	6.11	0.94	0.69	0.18	0.05	2.93			0.60	100.00			150	10		10	230		15	49	12	71	66	
6	5.19	3.27	1.94	0.70	0.19	0.15	5.70			3.10	100.20			300	20		20	660		14	96	23	140	47	
7	0.72	4.19	2.75	0.65	0.18	0.05	2.69			0.45	100.10			150	10		20	690		17	28	12	97	59	
9	2.98	5.39	1.57	0.66	0.21	0.10	3.69			1.90	100.00			220	-10		0	470		-1	48	15	110	54	

							2412	10	25			
						2	1032	22	91			
		37					1096	26	185			
							1268	18	76			
						2	3132	8	35			
							3468	4	24			
21	35	152	-10	489			41	10	87	71		32.0
93	48	124	-10	382			114	22	127	78		28.0
46	33	155	-10	382			67	14	92	66		26.0
24	9	130	-10	254			208	6	51	-25		12.0
24	25	156	-10	443			81	14	96	83		30.0
27	29	139	-10	433			85	15	97	76		25.0
13	15	130	-10	277			73	6	55	-25		21.0
23	33	140	-10	384			46	11	77	59		32.0
29	33	150	-10	438			28	10	75	61		27.0
46	32	154	-10	429			38	12	79	58		26.0
12	6	141	-10	252			78	6	56	16		14.0
17	24	136	-10	327			43	10	83	52		24.0
23	27	102	-10	408			104	35	184	75		-10.0
46	16	139	-10	386			55	6	63	30		11.0
45	25	121	17	348			185	25	143	66		31.0
15	23	126	21	322			31	9	88	42		21.0
-2	12	134	[illegible]	258			43	7	67	-25		13.0
[illegible]	[illegible]	[illegible]	[illegible]	237			120	6	90	-25		20.0

[illegible]	Y	Zr	Nb	Ba	Au (ppb)	Ga	Ni	Sc	V	Ce	Ge	La	Nd	Sm	Eu	Tb	Yb	Lu	Mo
-2	11	115	22	228			31	4	61	-25		15.0							
12	13	140	23	236			120	11	90	41		32.0							
-2	8	108	20	245			17	5	90	-25		14.0							
[illegible]	30	140	-10	399			50	10	86	61		30.0							
26	26	142	-10	440			80	13	88	79		27.0							
23	30	141	10	382			76	9	79	55		26.0							
28	36	147	10	401			65	11	86	55		18.0							
61	39	131	-10	380			56	18	111	69		27.0							
15	12	32	10	77			1432	21	53	-25		-10.0							
44	13	35	-10	105			1563	25	77	-25		-10.0							
39	32	70	-10	346			138	19	97	49		10.0							
[illegible]	34	64	-10	456			151	20	120	67		20.0							
33	26	235	20	547			151	13	97	199		123.0							
[illegible]	34	96	10	449			160	12	100	68		26.0							
[illegible]	39	90	10	251			150	42	211	46		-10.0							
[illegible]	18	129	21	-10			178	13	94	42		12.0							
[illegible]	16	96	17	-10			255	19	131	56		15.0							
[illegible]	18	101	17	-10			191	20	124	53		12.0							
[illegible]	58	176	-10	504			271	29	180	122		33.0							
[illegible]	18	129	109	204			82	6	57	-25		14.0							
	16	218	23	490			223	11	88	180		111.0							
[illegible]	32	113	10	266			137	27	110	56		21.0							
	13	130	7	300			147	9	73	26		15.0							
[illegible]	31	87	-10	420			278	24	101	59		26.0							
[illegible]	21	72	-10	242			289	23	79	-25		-10.0							
[illegible]	30	210	22	665			486	35	241	197		180.0							
[illegible]	14	102	19	238			372	20	98	47		24.0							
	38	243	13	443			332	18	175	133		49.0							
	23	166	16	236			425	19	144	56		13.0							
[illegible]	34	157	19	269			1952	20	136	72		31.0							
[illegible]	29	178	30	502			561	40	216	186		73.0							
28	24	233	22	468			163	11	86	165		99.0							
[illegible]	27	160	18	276			480	19	150	70		21.0							
[illegible]	27	165	29	561			571	23	166	128		84.0							
[illegible]	13	34	-10	69			2252	21	40	-25		-10.0							
[illegible]	12	28	-10	75			1300	14	46	-25		-10.0							
	-2	60	13	112			52	3	45	-25		4.0							
	10	21	8	63			3112	12	18	-25		-5.0							
	13	25	-5	[illegible]			1682	19	17	-25		-5.0							
	15	44	11	195			242	19	113	-25		11.0							
	9	22	10	67			2550	14	36	-25		-5.0							
	9	41	5	54			1496	22	26	-25		-5.0							
	8	31	9	[illegible]			1403	17	33	38		-5.0							
[illegible]	-10		10	20		-1	2400	5	100	2		0.2		-0.10	-0.05	-0.10	0.07	0.01	
	-10		10	10		-1	2700	5	100	6									
	-10		20	20		-1	2800	5	130	4									
	20		20	180		13	91	42	340	52									
	10		30	190		13	20	12	74	41			16.0	2.90	0.72	0.40	1.31	0.27	
	20		20	600		15	8	2	13	20									
	10		10	230		15	49	12	71	66									
	[illegible]		20	660		14	96	23	140	47									
	[illegible]		20	690		17	28	12	97	59									
	[illegible]		10	[illegible]		-1	48	15	110	54			22.0	4.10	1.35	0.50	1.64	0.28	

APPENDIX C-1: WHOLE ROCK ANALYSES:

MAJOR, TRACE, AND RARE EARTH ELEMENTS FROM

ROPES DEPOSIT

Whole rock analyses from Ropes deposit:

rock type codes:

AN = quartz - sericite - chlorite rock from north of microcrystalline carbonate - quartz layer
AS = quartz - sericite - chlorite rock from south of microcrystalline carbonate quartz - layer
B = carbonate - quartz chlorite rock
BC = microcrystalline carbonate - quartz rock
T = carbonate - talc rock
P = serpentinitic peridotite
BS = basalt dike
D = dacite crystal tuff
DF = dacite flow
DP = feldspar porphyritic dacite sill

for analyses in following table:

SiO_2 through SUM are in wt%

Cr through Lu are in ppm, except Au is in g/tonne

SAMPLE #	ROCK TYPE	TRAVERSE	DISTANCE	SiO2
RISO-14	AN	0	0	37.7
RISO-15	AN	0	0	60.0
RISO-19	AN	0	0	62.0
RISO-22	AN	0	0	30.6
RISO-16	AS	0	0	38.0
RISO-48	AS	3	98	50.5
RISO-18	AS	0	0	51.9
RISO-47	AS	3	120	52.3
RS-16-659	AS	2	122	57.6
RISO-30	AS	0	0	59.2
RISO-27	AS	0	0	61.9
RISO-44	AS	3	205	62.5
RS-16-750	AS	2	77	62.5
RS-26-126	AS	1	9	62.7
RS-26-145	AS	1	23	63.3
RISO-32	AS	0	0	64.5
RISO-43	AS	3	180	66.8
RS-16-786	AS	2	66	68.3
RISO-25	AS	0	0	79.4
RISO-42	AS	3	150	79.4
RISO-41	AS	0	0	84.2
RS-26-166	BC	1	37	13.2
RS-16-42	B	2	434	29.3
RISO-49	B	3	72	36.3
RS-26-113	B	1	0	37.8
RS-16-291	B	2	310	55.0
RS-16-162	B	2	374	56.4
RS-16-226	T	2	343	27.9
RS-26-191	T	1	55	29.0
RS-16-477	T	2	215	30.4
RISO-45	T	3	230	34.5
RISO-50	T	3	50	35.8
RISO-51	P	3	0	12.4
RS-26-259	P	1	101	29.4
RISO-46	P	3	260	35.4
RS-16-548	P	2	176	32.7
RS-17-221	P	0	0	33.4
RS-15-195	P	0	0	42.1
RS-8-389	P	0	0	33.8
RD-26-17	BS	0	0	47.0
MSL-28	D	0	0	65.7
MSL-37	D	0	0	74.8
SLU-2-121	D	0	0	62.4
SLU-3-373	DF	0	0	54.7
SLU-4-213	DP	0	0	64.5
SLU-3-168	D	0	0	60.0

SAMPLE #	Al2O3	Fe2O3	MgO	CaO	Na2O
RISO-14	25.00	9.49	11.00	0.69	0.17
RISO-15	17.30	6.41	6.04	0.31	0.14
RISO-19	15.70	5.44	5.34	0.81	0.16
RISO-22	17.60	7.84	11.10	8.09	0.20
RISO-16	25.10	6.00	13.60	2.07	0.15
RISO-48	5.93	5.40	12.60	8.53	0.08
RISO-18	15.00	8.70	11.70	0.84	0.75
RISO-47	11.50	6.93	7.41	6.33	0.10
RS-16-659	15.30	6.63	10.70	0.28	0.11
RISO-30	14.70	5.66	10.00	1.31	0.11
RISO-27	15.30	4.86	8.86	0.20	0.12
RISO-44	13.20	6.90	8.30	0.24	0.12
RS-16-750	17.80	4.07	5.45	0.23	0.16
RS-26-126	17.20	3.54	6.04	0.37	0.14
RS-26-145	13.90	6.51	6.42	0.37	0.11
RISO-32	12.10	5.88	9.24	0.14	0.12
RISO-43	15.60	4.54	3.58	0.36	0.14
RS-16-786	13.40	3.95	4.64	0.57	0.13
RISO-25	3.16	3.46	2.10	1.72	0.13
RISO-42	4.49	2.54	2.24	2.44	0.08
RISO-41	3.13	2.15	3.99	1.62	0.07
RS-26-166	1.22	3.96	18.80	25.00	0.08
RS-16-42	0.89	3.95	24.00	14.30	0.07
RISO-49	2.07	5.70	20.90	13.00	0.08
RS-26-113	3.81	6.15	14.20	14.50	0.09
RS-16-291	0.79	4.37	22.70	0.98	0.13
RS-16-162	1.48	4.91	28.80	0.67	0.07
RS-16-226	1.49	4.71	37.10	0.30	0.10
RS-26-191	1.82	5.86	25.00	14.10	0.10
RS-16-477	0.64	6.55	29.20	9.37	0.09
RISO-45	1.47	5.31	25.40	11.80	0.08
RISO-50	3.19	8.28	24.30	9.48	0.09
RISO-51	0.36	8.13	35.20	6.61	0.09
RS-26-259	0.33	6.96	32.80	4.84	0.06
RISO-46	1.26	6.57	36.20	1.26	0.12
RS-16-548	10.90	14.10	27.00	0.78	0.10
RS-17-221	0.66	7.85	38.90	0.23	0.01
RS-15-195	0.45	6.88	38.00	0.28	0.01
RS-8-389	0.46	9.10	35.70	4.06	0.01
RD-26-17	12.70	15.00	9.73	3.49	0.95
MSL-28	14.70	5.35	3.53	1.34	5.67
MSL-37	14.00	1.47	0.61	0.51	5.06
SLU-2-121	16.00	5.13	4.60	0.85	6.11
SLU-3-373	15.20	7.54	5.46	5.19	3.27
SLU-4-213	16.00	4.95	3.27	0.72	4.19
SLU-3-168	15.30	6.28	3.69	2.98	5.39

SAMPLE #	K2O	TiO2	P2O5	MnO	LOI
RISO-14	6.35	1.21	0.37	0.07	8.00
RISO-15	4.31	0.73	0.21	0.04	4.85
RISO-19	4.37	0.67	0.21	0.05	4.93
RISO-22	4.52	0.66	0.26	0.36	13.00
RISO-16	5.12	1.29	1.58	0.03	7.62
RISO-48	0.10	0.31	0.18	0.15	13.50
RISO-18	2.82	1.32	0.15	0.06	6.47
RISO-47	2.54	0.70	0.20	0.12	11.20
RS-16-659	2.17	0.74	0.19	0.03	5.77
RISO-30	2.30	0.82	0.93	0.05	5.08
RISO-27	3.18	0.47	0.13	0.03	4.93
RISO-44	2.21	0.67	0.15	0.05	5.08
RS-16-750	4.49	0.56	0.12	0.02	4.47
RS-26-126	4.63	0.72	0.17	0.01	4.39
RS-26-145	3.12	0.85	0.14	0.01	5.00
RISO-32	1.93	0.58	0.10	0.02	5.16
RISO-43	4.29	0.63	0.25	0.01	3.77
RS-16-786	3.33	0.43	0.05	0.02	4.00
RISO-25	0.78	0.12	0.04	0.05	3.77
RISO-42	0.36	0.24	0.04	0.04	3.47
RISO-41	0.16	0.11	0.05	0.04	3.16
RS-26-166	0.02	0.07	0.02	0.11	38.10
RS-16-42	0.01	0.04	0.02	0.09	27.90
RISO-49	0.01	0.10	0.02	0.10	21.10
RS-26-113	0.02	0.17	0.02	0.21	22.40
RS-16-291	0.01	0.05	0.01	0.04	14.60
RS-16-162	0.01	0.07	0.01	0.02	6.00
RS-16-226	0.01	0.09	0.01	0.15	28.40
RS-26-191	0.01	0.08	0.02	0.11	23.80
RS-16-477	0.01	0.04	0.01	0.11	23.80
RISO-45	0.01	0.08	0.02	0.18	20.30
RISO-50	0.01	0.15	0.02	0.18	17.80
RISO-51	0.02	0.04	0.02	0.17	37.00
RS-26-259	0.01	0.03	0.02	0.12	25.50
RISO-46	0.02	0.07	0.02	0.12	18.70
RS-16-548	0.01	0.80	0.12	0.04	11.90
RS-17-221	0.01	0.06	0.01	0.17	18.60
RS-15-195	0.02	0.05	0.01	0.05	11.70
RS-8-389	0.01	0.05	0.01	0.13	15.80
RD-26-17	0.62	1.83	0.23	0.14	8.23
MSL-28	0.74	0.66	0.16	0.10	2.23
MSL-37	2.48	0.18	0.05	0.02	0.85
SLU-2-121	0.94	0.69	0.18	0.05	2.93
SLU-3-373	1.94	0.70	0.19	0.15	5.70
SLU-4-213	2.78	0.65	0.18	0.05	2.69
SLU-3-168	1.57	0.68	0.21	0.10	3.69

SAMPLE #	H2O	CO2	SUM	Cr	Rb
RISO-14	5.10	0.40	100.10	40	200
RISO-15	3.30	0.10	100.40	50	160
RISO-19	3.10	0.90	99.70	40	140
RISO-22	2.90	12.30	94.30	10	140
RISO-16	4.60	0.10	100.70	140	170
RISO-48	3.10	12.20	97.40	490	20
RISO-18	5.20	1.10	99.80	130	60
RISO-47	2.90	8.90	99.50	600	100
RS-16-659	4.40	0.09	99.60	190	70
RISO-30	4.40	0.09	100.20	110	120
RISO-27	3.90	0.10	100.00	60	130
RISO-44	4.00	0.10	99.50	180	90
RS-16-750	3.00	0.09	99.90	110	150
RS-26-126	3.30	0.20	100.00	100	150
RS-26-145	3.20	0.20	99.80	140	100
RISO-32	3.90	0.09	99.80	170	90
RISO-43	2.70	0.10	99.80	110	140
RS-16-786	2.60	1.00	98.90	60	100
RISO-25	0.70	2.80	94.80	170	5
RISO-42	0.90	3.60	96.40	150	5
RISO-41	1.60	2.20	98.70	140	20
RS-26-166	0.09	37.10	100.50	280	10
RS-16-42	1.90	25.90	100.70	880	20
RISO-49	1.20	19.60	99.60	1080	20
RS-26-113	2.20	21.10	99.50	1180	20
RS-16-291	1.70	14.00	98.90	1450	10
RS-16-162	3.70	1.30	98.70	1080	40
RS-16-226	[illegible]	25.10	100.30	[illegible]	10
RS-26-191	[illegible]	21.00	100.10	1660	10
RS-16-477	2.20	22.50	100.60	2480	10
RISO-45	3.00	18.20	99.50	2010	5
RISO-50	3.70	14.20	99.60	2450	10
RISO-51	1.70	35.90	100.50	3200	5
RS-26-259	1.80	23.20	100.60	2740	10
RISO-46	6.10	11.40	100.00	1840	5
RS-16-548	8.00	1.10	98.60	620	5
RS-17-221	8.60	9.50	100.40	3284	10
RS-15-195	1.10	0.66	100.20	4310	10
RS-8-389	9.80	5.90	100.00	5884	5
RD-26-17	5.20	4.80	100.00	137	30
MSL-28	2.20	0.10	100.30	68	10
MSL-37	0.90	0.01	100.10	68	60
SLU-2-121	2.70	0.60	100.00	68	20
SLU-3-373	3.00	3.10	100.20	205	60
SLU-4-213	2.10	0.45	100.10	68	90
SLU-3-168	2.00	1.90	100.00	137	60

SAMPLE #	Sr	Y	Zr	Nb	Au
RISO-14	10	20	260	10	2.297
RISO-15	5	5	150	20	0.309
RISO-19	20	10	130	20	1.680
RISO-22	50	30	120	10	4.937
RISO-16	70	60	410	20	61.954
RISO-48	190	20	90	20	0.034
RISO-18	30	40	80	10	0.103
RISO-47	80	40	100	10	0.034
RS-16-659	5	10	130	20	0.034
RISO-30	50	20	240	30	0.069
RISO-27	20	5	130	30	8.914
RISO-44	5	10	110	5	0.034
RS-16-750	10	5	160	10	0.034
RS-26-126	10	5	100	20	0.034
RS-26-145	5	10	80	20	0.034
RISO-32	10	5	120	10	3.806
RISO-43	10	20	150	10	0.034
RS-16-786	5	5	130	5	0.034
RISO-25	10	5	20	40	4.080
RISO-42	50	5	30	10	0.034
RISO-41	5	5	5	10	
RS-26-166	530	5	5	20	
RS-16-42	420	10	5	20	
RISO-49	330	5	5	10	
RS-26-113	190	5	20	10	
RS-16-291	5	5	5	5	
RS-16-162	10	5	5	20	
RS-16-226	5	5	5	20	
RS-26-191	250	10	5	20	
RS-16-477	120	5	5	20	
RISO-45	210	10	5	10	
RISO-50	150	5	5	10	
RISO-51	190	5	5	10	
RS-26-259	90	5	5	20	
RISO-46	30	5	5	10	
RS-16-548	5	20	70	20	
RS-1[illegible]-221	5	5	170	10	
RS-15-195	5	5	5	10	
RS-8-389	5	5	5	20	
RD-26-17	40	20	160	20	
MSL-28	190	20	130	30	
MSL-37	120	20	90	20	
SLU-2-121	150	10	160	10	
SLU-3-373	300	20	110	20	
SLU-4-213	100	10	160	20	
SLU-3-168	220	5	160	10	

SAMPLE #	Ga	Ni	Sc	V	Ce
RISO-14	23	58	21.7	200	103
RISO-15	13	56	13.3	120	61
RISO-19	19	28	13.3	110	66
RISO-22	18	46	12.7	150	82
RISO-16	22	150	23.0	200	376
RISO-48	7	360	10.4	70	120
RISO-18	15	120	51.8	370	36
RISO-47	14	140	18.6	150	42
RS-16-659	15	160	19.0	130	70
RISO-30	14	100	14.4	140	210
RISO-27	18	51	8.8	92	40
RISO-44	13	120	16.8	120	35
RS-16-750	20	58	9.2	84	49
RS-26-126	19	130	17.4	120	41
RS-26-145	14	190	20.8	180	63
RISO-32	11	120	12.6	150	46
RISO-43	19	170	11.6	98	59
RS-16-786	15	71	7.5	72	36
RISO-25	4	71	2.4	36	1
RISO-42	6	38	4.0	46	16
RISO-41	3	44	2.8	40	9
RS-26-166	2	290	4.8	30	7
RS-16-42	2	1100	5.1	32	1
RISO-49	3	1300	9.2	48	3
RS-26-113	5	940	13.4	74	4
RS-16-291	2	1700	4.9	36	3
RS-16-162	3	2600	5.4	50	6
RS-16-226	2	2900	10.0	28	2
RS-26-191	2	2400	7.3	38	2
RS-16-477	1	2700	5.2	20	1
RISO-45	3	2200	7.6	34	3
RISO-50	4	1700	14.0	66	3
RISO-51	1	2500	4.3	22	1
RS-26-259	3	2200	3.5	14	1
RISO-46	2	2500	6.6	26	4
RS-16-548	9	1100	26.4	160	37
RS-17-221	0.5	2400	5.0	100	2
RS-15-195	0.5	2700	5.1	100	
RS-8-389	0.5	2800	5.2	130	
RD-26-17	13	91	42.3	340	
MSL-28	13	20	11.6	74	41
MSL-37	15	8	2.4	13	
SLU-2-121	15	49	12.3	71	
SLU-3-373	14	96	23.0	140	
SLU-4-213	17	28	12.1	97	
SLU-3-168	0.5	48	15.0	110	54

SAMPLE #	Ge	La	Nd	Sm	Eu
RISO-14	10				
RISO-15					
RISO-19	10	34.3	28	4.87	1.15
RISO-22					
RISO-16	10				
RISO-48	10	65.8	48	8.05	1.82
RISO-18					
RISO-47	10				
RS-16-659					
RISO-30	10				
RISO-27					
RISO-44	10				
RS-16-750					
RS-26-126		20.1	16	2.68	0.72
RS-26-145					
RISO-32	20				
RISO-43	20				
RS-16-786					
RISO-25					
RISO-42	20				
RISO-41					
RS-26-166		2.5	3	0.55	0.29
RS-16-42					
RISO-49	10	1.3	3	0.32	0.14
RS-26-113					
RS-16-291					
RS-16-162					
RS-16-226					
RS-26-191					
RS-16-477					
RISO-45	10				
RISO-50	10				
RISO-51	10				
RS-26-259					
RISO-46	10	0.8	3	0.19	0.11
RS-16-548					
RS-17-221		0.2	3	0.10	0.05
RS-15-195					
RS-8-389					
RD-26-17					
MSL-28		23.3	16	2.90	0.72
MSL-37					
SLU-2-121					
SLU-3-373					
SLU-4-213					
SLU-3-168		33.3	22	4.10	1.35

SAMPLE #	Tb	Yb	Lu	
RISO-14				
RISO-15				
RISO-19	0.5	1.63	0.29	
RISO-22				
RISO-16				
RISO-48	0.7	1.06	0.15	
RISO-18				
RISO-47				
RS-16-659				
RISO-30				
RISO-27				
RISO-44				
RS-16-750				
RS-26-126	0.3	1.02	0.16	
RS-26-145				
RISO-32				
RISO-43				
RS-16-786				
RISO-25				
RISO-42				
RISO-41				
RS-26-166	0.1	0.27	0.04	
RS-16-42				
RISO-49	0.1	0.28	0.04	
RS-26-113				
RS-16-291				
RS-16-162				
RS-16-226				
RS-26-191				
RS-16-477				
RISO-45				
RISO-50				
RISO-51				
RS-26-259				
RISO-46	0.1	0.24	0.03	
RS-16-548				
RS-17-221	0.1	0.07	0.01	
RS-15-195				
RS-8-389				
RD-26-17				
MSL-28	0.4	1.31	0.27	
MSL-37				
SLU-2-121				
SLU-3-373				
SLU-4-213				
SLU-3-163	0.5	1.64	0 28	

APPENDIX C-2: CORRELATION MATRIX AND SUMMARY STATISTICS

USING WHOLE ROCK ANALYSES FROM ROPES DEPOSIT

(USING ANALYSES FOR FIRST 36 SAMPLES IN APPENDIX C-1)

CORRELATION MATRIX USING WHOLE ROCK ANALYSES

FROM ROPES DEPOSIT

ELEMENT CORRELATIONS ROPES MINE WHOLE ROCK DATA — 15:16 THURSDAY, JANUARY 23, 1986 — 1

VARIABLE	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
TRAVERSE	36	1.5000	1.2271	54.00	0	3.000
DISTANCE	36	102.9722	122.7015	3707.00	0	434.000
SIO2	36	48.6333	12.3656	1750.40	12.400	54.200
AL2O3	36	8.3761	7.1514	301.54	0.370	25.000
FE2O3	36	5.9003	2.1592	212.41	2.150	14.100
MGO	36	15.6097	10.7489	561.95	2.100	37.100
CAO	36	4.5697	5.9575	164.51	0.140	25.000
NA2O	36	0.1289	0.1112	4.64	0.040	0.750
K2O	36	1.7574	1.9372	63.26	0.009	6.350
TIO2	36	0.4364	0.3559	15.71	0.070	1.320
P2O5	36	0.1633	0.2941	5.88	0.010	1.580
MNO	36	0.0836	0.0736	3.01	0.010	0.360
LOI	36	12.9144	10.0795	464.92	3.160	38.100
H2O	36	3.0886	1.5515	111.19	0.090	8.000
CO2	36	9.[illegible]61	11.1773	335.26	0.090	37.100
SUM	36	99.[illegible]11	1.4790	3577.00	94.300	100.700
CR	36	746.9444	992.5007	26890.00	10.000	3200.000
RB	36	65.2778	62.1357	2350.00	5.000	200.000
SR	36	88.4722	127.2389	3185.00	5.000	530.000
Y	36	12.2222	12.5610	440.00	5.000	60.000
ZR	36	80.5556	90.4949	2900.00	5.000	410.000
NB	36	15.4167	9.1394	555.00	0	40.000

ELEMENT CORRELATIONS ROPES MINE WHOLE ROCK DATA 15:16 THURSDAY, JANUARY 23, 1986 2

CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / NUMBER OF OBSERVATIONS

	TRAVERSE	DISTANCE	SIO2	AL2O3	FE2O3	MGO	CAO	NA2O	K2O	TIO2	P2O5	MNO	LOI
TRAVERSE	1.00000 0.0000 36	0.57744 0.0002 36	-0.19702 0.2496 36	-0.36853 0.0269 36	0.01836 0.9131 36	0.36973 0.0265 36	0.18361 0.2701 36	-0.32340 0.0544 36	-0.45609 0.0052 36	-0.43157 0.0056 36	-0.36946 0.0266 36	0.14639 0.3943 36	0.30821 0.0674 36
DISTANCE	0.57744 0.0002 36	1.00000 0.0000 36	-0.13544 0.2799 36	-0.43674 0.0078 36	-0.15611 0.5379 36	0.53097 0.0009 36	0.03491 0.8399 36	-0.24186 0.1553 36	-0.46270 0.0045 36	-0.43943 0.0073 36	-0.30352 0.0719 36	-0.01214 0.9440 36	0.26719 0.1152 36
SIO2	-0.19702 0.2496 36	-0.13544 0.2799 36	1.00000 0.0000 36	0.41057 0.0129 36	-0.45811 0.0050 36	-0.76449 0.0001 36	-0.63261 0.0001 36	0.09030 0.6005 36	0.33039 0.0491 36	0.25299 0.1366 36	0.04226 0.8067 36	-0.62495 0.0001 36	-0.85244 0.0001 36
AL2O3	-0.36853 0.0269 36	-0.43674 0.0078 36	0.41057 0.0129 36	1.00000 0.0000 36	0.22923 0.1934 36	-0.65322 0.0001 36	-0.50724 0.0015 36	0.35637 0.0329 36	0.55279 0.0001 36	0.77340 0.0001 36	0.22504 0.1870 36	-0.27110 0.1098 36	-0.65543 0.0001 36
FE2O3	0.01836 0.9131 36	-0.15611 0.5379 36	-0.45811 0.0050 36	0.22923 0.1934 36	1.00000 0.0000 36	0.32515 0.0530 36	-0.06162 0.7211 36	0.24452 0.1507 36	0.06170 0.7207 36	0.39876 0.0160 36	0.09150 0.5956 36	0.24282 0.1536 36	0.12289 0.4752 36
MGO	0.36973 0.0265 36	0.53097 0.0009 36	-0.76449 0.0001 36	-0.65322 0.0001 36	0.32515 0.0530 36	1.00000 0.0000 36	0.32671 0.0516 36	-0.19192 0.2621 36	-0.63356 0.0001 36	-0.52596 0.0010 36	-0.24550 0.1490 36	0.40403 0.0145 36	0.77279 0.0001 36
CAO	0.18361 0.2701 36	0.03491 0.8399 36	-0.63261 0.0001 36	-0.50724 0.0015 36	-0.06162 0.7211 36	0.32671 0.0516 36	1.00000 0.0000 36	-0.22820 0.1807 36	-0.47496 0.0034 36	-0.48505 0.0027 36	-0.22373 0.1896 36	0.55795 0.0004 36	0.75339 0.0001 36
NA2O	-0.32340 0.0544 36	-0.24186 0.1553 36	0.09030 0.6005 36	0.35637 0.0329 36	0.24452 0.1507 36	-0.19192 0.2621 36	-0.22820 0.1807 36	1.00000 0.0000 36	0.32962 0.0498 36	0.55013 0.0005 36	0.10274 0.5510 36	-0.06268 0.7165 36	-0.24115 0.1565 36
K2O	-0.45609 0.0052 36	-0.46270 0.0045 36	0.33039 0.0491 36	0.55279 0.0001 36	0.06170 0.7207 36	-0.63356 0.0001 36	-0.47496 0.0034 36	0.32962 0.0498 36	1.00000 0.0000 36	0.60935 0.0001 36	0.51841 0.0012 36	-0.27364 0.1063 36	-0.60239 0.0001 36
TIO2	-0.43157 0.0056 36	-0.43943 0.0073 36	0.25299 0.1366 36	0.77340 0.0001 36	0.39876 0.0160 36	-0.52596 0.0010 36	-0.48505 0.0027 36	0.55013 0.0005 36	0.60935 0.0001 36	1.00000 0.0000 36	0.63590 0.0001 36	-0.31871 0.0582 36	-0.59494 0.0001 36
P2O5	-0.36946 0.0266 36	-0.30352 0.0719 36	0.04226 0.8067 36	0.22504 0.1870 36	0.09150 0.5956 36	-0.24550 0.1490 36	0.22373 0.1896 36	0.10274 0.5510 36	0.51841 0.0012 36	0.63590 0.0001 36	1.00000 0.0000 36	-0.17147 0.3173 36	-0.30213 0.0733 36
MNO	0.14639 0.3943 36	-0.01214 0.9440 36	-0.62495 0.0001 36	-0.27110 0.1098 36	0.24282 0.1536 36	0.40403 0.0145 36	0.55795 0.0004 36	-0.06268 0.7165 36	-0.27364 0.1063 36	-0.31871 0.0582 36	-0.17147 0.3173 36	1.00000 0.0000 36	0.58276 0.0002 36
LOI	0.30821 0.0674 36	0.26719 0.1152 36	-0.85244 0.0001 36	-0.65543 0.0001 36	0.12289 0.4752 36	0.77279 0.0001 36	0.75339 0.0001 36	-0.24115 0.1565 36	-0.60239 0.0001 36	-0.59494 0.0001 36	-0.30213 0.0733 36	0.58276 0.0002 36	1.00000 0.0000 36

ELEMENT CORRELATIONS ROBTS MINE WHOLE ROCK DATA 15:16 THURSDAY, JANUARY 23, 1986 3

CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / NUMBER OF OBSERVATIONS

	TRAVERSE	DISTANCE	SIO2	AL2O3	FE2O3	MGO	CAO	NA2O	K2O	TIO2	P2O5	MNO	LOI
H2O	-0.06934 0.6044 36	-0.00330 0.9847 36	-0.02427 [illegible] 36	[illegible] [illegible] 35	0.64346 0.0001 36	0.07417 0.6663 36	-0.46637 0.0041 36	0.30570 0.0695 36	0.30135 0.0735 36	0.60354 0.0001 36	0.32963 0.0495 36	-0.17327 0.3122 36	-0.35070 0.0360 36
CO2	0.31[illegible] 0.0353 36	0.24639 0.1431 35	-0.73734 0.0001 35	-0.55370 0.0001 36	-0.01659 0.9231 36	0.69116 0.0001 36	0.78790 0.0001 36	-0.26443 0.1191 36	-0.63029 0.0001 36	-0.67531 0.0001 35	-0.36014 0.0310 36	0.61615 0.0001 35	0.97941 0.0001 36
SUM	0.0[illegible]431 0.7953 36	0.09824 0.5535 36	-0.33366 0.0427 35	[illegible] 0.7924 35	0.10124 0.5559 36	0.35216 0.0478 36	0.08077 0.6396 36	-0.01593 0.9337 36	0.04010 0.8154 35	0.08011 0.6426 35	0.13944 0.4173 36	-0.29223 0.0837 35	0.30663 0.0589 36
CR	0.46463 0.0053 35	0.39[illegible]03 0.0[illegible]91 35	-0.61549 0.0001 34	-0.57532 0.0001 34	0.22059 0.1959 36	0.30712 0.0001 36	0.37691 0.0235 36	-0.25344 0.1270 36	-0.63343 0.0001 35	-0.62525 0.0001 36	-0.33735 0.0439 35	0.43312 0.0083 35	0.70065 0.0001 36
RB	-0.45434 0.0053 36	-0.42590 0.0096 35	0.32914 0.0507 34	0.47343 0.0031 35	0.03596 0.8351 36	-0.50386 0.0001 36	-0.46034 0.0047 36	0.21150 0.2155 36	0.97315 0.0001 35	0.77312 0.0001 35	0.55959 0.0004 35	-0.29344 0.0524 36	-0.59348 0.0001 36
SR	0.22369 0.1397 36	0.10663 0.5359 35	-0.62625 0.0001 35	-0.51140 0.0014 36	-0.11279 0.5115 36	0.34279 0.0406 36	0.94263 0.0001 35	-0.21671 0.2043 35	-0.46130 0.0045 35	-0.45358 0.0055 36	-0.16931 0.3231 34	0.33183 0.0216 36	0.75622 0.0001 36
Y	-0.19786 0.2474 36	-0.19312 0.2591 35	-0.09265 0.5910 34	[illegible] 0.1796 35	0.34250 0.0435 36	-0.18531 0.2793 36	-0.09031 0.6004 35	0.45471 0.0053 36	0.43592 0.0079 35	0.65911 0.0001 36	0.73241 0.0001 36	0.03073 0.6397 36	-0.20255 0.2361 36
ZR	-0.41596 0.0117 36	-0.41046 0.0127 36	0.22613 0.1545 34	0.53602 0.0001 35	0.14160 0.4107 36	-0.47598 0.0031 36	-0.42201 0.0104 35	0.19467 0.2509 35	0.31957 0.0031 34	0.82546 0.0001 36	0.56471 0.0001 35	-0.31016 0.0656 36	-0.53397 0.0009 36
NB	-0.45903 0.0050 36	-0.16349 0.3407 35	0.09819 0.5090 34	-0.01379 0.9356 35	-0.11317 0.5214 35	-0.12107 0.5575 36	-0.00530 0.9732 34	-0.13062 0.4484 35	0.00257 0.9854 36	0.02370 0.8630 36	0.21965 0.1932 34	-0.20298 0.2351 36	-0.06819 0.6927 35
AU	-0.22539 0.2061 20	-0.25423 0.2794 20	-0.40373 0.0773 20	-0.44316 0.0492 20	0.03952 0.8693 20	0.41604 0.0695 20	0.03283 0.8907 20	-0.07925 0.8326 20	0.29712 0.2144 20	0.41053 0.0721 20	0.92215 0.0001 20	-0.04528 0.8496 20	0.12247 0.6070 20

	H2O	CO2	SUM	CR	RB	SR	Y	ZR	NB	AU
TRAVERSE	-0.06934 0.6044 36	0.31[illegible] 0.0353 35	0.0[illegible]431 0.7953 35	0.46463 0.0053 35	-0.45434 0.0053 36	0.22369 0.1397 36	-0.19786 0.2474 36	-0.41596 0.0117 36	-0.45903 0.0050 35	-0.22539 0.2061 20
DISTANCE	-0.00330 0.9847 36	0.24639 0.1431 35	0.09824 0.5535 35	0.39[illegible]03 0.0[illegible]91 35	-0.42590 0.0096 34	0.10663 0.5359 36	-0.19312 0.2591 36	-0.41046 0.0127 36	-0.16349 0.3407 35	-0.25423 0.2794 20
SIO2	-0.02427 0.8883 36	-0.73734 0.0001 35	-0.33366 0.0427 35	-0.61549 0.0001 34	0.32914 0.0507 34	-0.62625 0.0001 36	-0.09265 0.5910 35	0.22613 0.1545 35	0.09819 0.5090 35	-0.40373 0.0773 20

ELEMENT CORRELATIONS ROPES MINE WHOLE ROCK DATA 15:16 THURSDAY, JANUARY 23, 1986 4

CORRELATION COEFFICIENTS / PROB > |R| UNDER H0:RHO=0 / NUMBER OF OBSERVATIONS

	H2O	CO2	SUM	CR	RB	SR	Y	ZR	NB	AU
AL2O3	0.43610 0.0078 36	-0.65576 0.0001 36	-0.04544 0.7924 36	-0.67536 0.0001 36	0.83948 0.0001 36	-0.51160 0.0014 36	0.22936 0.1784 36	0.62600 0.0001 36	-0.01079 0.9502 36	-0.44516 0.0492 20
FE2O3	0.69346 0.0001 36	-0.01646 0.9241 36	0.10126 0.5568 36	0.22069 0.1959 36	0.03596 0.8351 36	-0.11299 0.5118 36	0.34260 0.0408 36	0.14163 0.4107 36	-0.11037 0.5216 36	0.03952 0.4683 20
MGO	0.07917 0.6453 36	0.69116 0.0001 36	0.33216 0.0475 36	0.80712 0.0001 36	-0.60856 0.0001 36	0.34299 0.0406 36	-0.18531 0.2793 36	-0.49608 0.0021 36	-0.10107 0.5575 36	0.41404 0.0695 20
CAO	-0.46637 0.0041 36	0.75790 0.0001 36	0.06377 [illegible] 36	0.37681 0.0235 36	-0.46036 0.0047 36	0.94263 0.0001 36	-0.09031 0.6004 36	-0.42201 0.0104 36	-0.00580 0.9733 36	0.03283 0.8907 20
NA2O	0.30570 0.0698 36	-0.26663 0.1161 36	-0.01503 0.9307 36	-0.25846 0.1280 36	0.21150 0.2155 36	-0.21671 0.2043 36	0.45671 0.0053 36	0.19467 0.2507 36	-0.13042 0.4464 36	-0.02925 0.9026 20
K2O	0.30135 0.0735 36	-0.63035 0.0001 36	0.04910 0.7764 36	-0.63349 0.0001 36	0.97314 0.0001 36	-0.46189 0.0046 36	0.43560 0.0079 36	0.81957 0.0001 36	0.00252 0.9884 36	0.29019 0.2146 20
TIO2	0.60304 0.0001 36	-0.67531 0.0001 36	0.05011 0.7724 36	-0.62525 0.0001 36	0.77312 0.0001 36	-0.45358 0.0055 36	0.65911 0.0001 36	0.82546 0.0001 36	0.02970 0.8630 36	0.41043 0.0721 20
P2O5	0.32963 0.0495 36	-0.35014 0.0310 36	0.11946 0.4873 36	-0.33795 0.0439 36	0.55869 0.0004 36	-0.16981 0.3221 36	0.73261 0.0001 36	0.86671 0.0001 36	0.21965 0.1980 36	0.82915 0.0001 20
MNO	-0.17327 0.3122 36	0.51615 0.0001 36	-0.24224 0.1557 36	0.47312 0.0035 36	-0.29344 0.0824 36	0.38183 0.0216 36	0.08073 0.6397 36	-0.31015 0.0656 36	-0.20298 0.2351 36	-0.04523 0.8496 20
LOI	-0.35070 0.0360 36	0.97641 0.0001 36	0.30563 0.0699 36	0.73005 0.0001 36	-0.59868 0.0001 36	0.75422 0.0001 36	-0.20255 0.2361 36	-0.53397 0.0008 36	-0.06319 0.6927 36	0.12247 0.6070 20
H2O	1.00000 0.0000 36	-0.51330 0.0014 36	0.17654 0.3030 36	-0.15092 0.3795 36	0.31379 0.0624 36	-0.45030 0.0059 36	0.38953 0.0189 36	0.43501 0.0080 36	-0.08963 0.6032 36	0.24318 0.3015 20
CO2	-0.51330 0.0014 36	1.00000 0.0000 36	0.20343 0.2339 36	0.65663 0.0001 36	-0.43020 0.0091 36	0.77151 0.0001 36	-0.25228 0.1377 36	-0.59699 0.0001 36	-0.07036 0.6834 36	-0.10847 0.6494 20
SUM	0.17654 0.3030 36	0.20343 0.2339 36	1.00000 0.0000 36	0.27241 0.1080 36	0.11910 0.4890 36	0.21260 0.2132 36	-0.04058 0.8142 36	0.12515 0.4671 36	-0.08702 0.6114 36	0.16496 0.4871 20

ELEMENT CORRELATIONS ROPES MINE WHOLE ROCK DATA

CORRELATION COEFFICIENTS / PROB > |R| UNDER H0:RHO=0 / NUMBER OF OBSERVATIONS

	H2O	CO2	SUM	CR	RB	SR	Y	ZR	NB	AU
CR	-0.15082 0.3796 36	0.69653 0.0001 35	0.27241 0.1080 36	1.00000 0.0000 36	-0.52638 0.0011 36	0.33290 0.0475 36	-0.35297 0.0374 35	-0.56764 0.0003 36	-0.18516 0.2796 36	-0.06942 0.7712 20
RB	0.31379 0.0624 36	-0.63620 0.0001 35	0.11510 0.4990 36	-0.52638 0.0011 36	1.00000 0.0000 36	-0.43633 0.0078 36	0.39971 0.0157 36	0.84491 0.0001 36	0.03504 0.8392 36	0.28761 0.2192 20
SR	-0.45032 0.0058 36	0.77151 0.0001 35	0.21250 0.2132 35	0.33290 0.0473 36	-0.43633 0.0078 36	1.00000 0.0000 36	-0.09837 0.5681 36	-0.36395 0.0292 36	0.03926 0.8202 35	0.18027 0.4469 20
Y	0.35353 0.0359 36	-0.25223 0.1377 35	-0.04053 0.8142 35	-0.35297 0.0374 35	0.39971 0.0157 36	-0.09837 0.5681 36	1.00000 0.0000 36	0.63724 0.0001 36	-0.00932 0.9570 36	0.64101 0.0023 20
ZR	0.43501 0.0080 36	-0.53699 0.0001 35	0.12515 0.4671 35	-0.56764 0.0003 36	0.84491 0.0001 36	-0.36395 0.0292 36	0.63724 0.0001 36	1.00000 0.0000 36	0.11507 0.5039 35	0.73766 0.0002 20
NB	-0.03983 0.8032 36	-0.07036 0.6884 35	-0.03762 0.8114 35	-0.18516 0.2796 36	0.03504 0.8392 36	0.03926 0.8202 36	-0.00932 0.9570 36	0.11507 0.5039 36	1.00000 0.0000 35	0.15302 0.5195 20
AU	0.24318 0.3015 20	-0.10667 0.6534 20	0.18436 0.4371 20	-0.06942 0.7712 20	0.28761 0.2192 20	0.18027 0.4469 20	0.64101 0.0023 20	0.73766 0.0002 20	0.15302 0.5195 20	1.00000 0.0000 20

SUMMARY STATISTICS: WHOLE ROCK ANALYSES

FROM ROPES DEPOSIT

rock type codes:

AN = quartz - sericite - chlorite rock (north of microcrystalline carbonate - quartz - layer)

AS = quartz - sericite - chlorite rock (south of microcrystalline carbonate - quartz layer)

B = carbonate - quartz - chlorite rock

BC = microcrystalline carbonate - quartz rock

T = carbonate - talc rock

P = serpentinitic peridotite

wt.%	mean	std.dev.	high	low
Si02	62.65	11.44	84.2	38
Al203	11.42	5.32	17.8	2.51
Fe203	5.16	1.74	8.7	2.15
Mg0	7.46	3.56	13.6	2.1
Ca0	1.62	2.33	8.53	0.14
Na20	0.15	0.15	0.75	0.07
K20	2.56	1.57	5.12	0.1
Ti02	0.62	0.34	0.32	0.11
P205	0.26	0.4	1.58	0.04
Mn0	0.04	0.04	0.15	0.01
LOI	5.7	2.77	13.5	3.16
H20	3.2	1.26	5.2	0.7
C02	1.94	3.46	1.22	0.09
SUM	99.1	1.53	100.7	94.8
ppm				
Cr	179.41	143.81	600	60
Rb	89.41	52.7	170	5
Sr	33.23	47.13	190	5
Y	15.88	16.22	60	5
Zr	122.65	92.7	410	5
Nb	16.47	9.8	40	5
Au	4.93	15.38	61.88	0.03

AN N-4

wt. %	mean	std dev	high	low
Si02	47.58	15.79	62	30.6
Al203	18.9	4.15	25	15.7
Fe203	7.3	1.76	9.49	5.44
Mg0	8.37	3.11	11.1	5.34
Ca0	2.48	3.75	8.09	0.31
Na20	0.17	0.02	0.2	0.14
K20	4.89	0.98	6.35	4.31
Ti02	0.82	0.26	1.21	0.66
P205	0.26	0.08	0.37	0.21
Mn0	0.13	0.15	0.36	0.04
LO1	7.7	3.83	13	4.85
H20	3.6	1.01	5.1	2.9
C02	3.42	5.92	12.3	0.1
SUM	98.62	2.9	100.4	94.3
ppm				
Cr	35	17.32	50	10
Rb	160	28.28	200	140
Sr	21.25	20.16	50	5
Y	16.25	11.09	30	5
Zr	165	64.55	260	120
Nb	15	5.77	20	10
Au	2.29	1.92	4.93	0.31

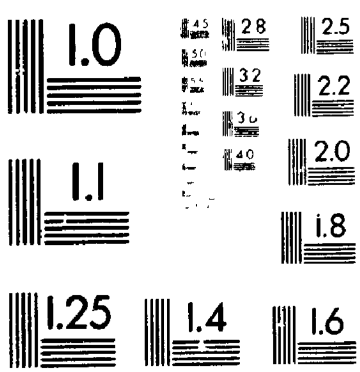
B N=5

wt %	Mean	std dev.	high	low
Si02	42.96	12.07	56.4	29.3
Al203	1.81	1.23	3.81	0.79
Fe203	5.02	0.911	6.15	3.95
Mg0	22.12	5.31	28.8	14.2
Ca0	8.69	7.2	14.5	0.67
Na20	0.09	0.02	0.13	0.07
K20	0.01	0	0.02	0.01
Ti02	0.09	0.05	0.17	0.04
P205	0.02	0.01	0.02	0.01
Mn0	0.09	0.07	0.21	0.02
LOI	18.4	8.39	27.9	6
H20	2.14	0.94	3.7	1.2
C02	16.38	9.44	25.9	1.3
SUM	99.48	0.78	100.7	98.7
ppm				
Cr	1134	207.56	1450	880
Rb	22	10.95	40	10
Sr	191	186.49	420	5
Y	6	2.24	10	5
Zr	8	6.71	20	5
Nb	13	6.71	20	5

BC N=1

wt%	mean
Si02	13.2
Al203	1.22
Fe203	3.96
Mg0	18.8
Ca0	25
Na20	0.08
K20	0.02
Ti02	0.07
P205	0.02
Mn0	0.11
LOI	38.1
H20	0.09
C02	37.1
SUM	100.5
ppm	
Cr	280
Rb	10
Sr	530
Y	5
Zr	5
Nb	20

7



T N=5

wt/%	mean	std dev	high	low
Sio2	31.52	3.46	35.8	27.9
AL203	1.72	0.93	3.19	0.64
FE203	6.14	1.37	8.28	4.71
MG0	28.2	5.33	37.1	24.3
CA0	9.01	5.24	14.1	0.3
NA20	0.09	0.01	0.1	0.08
K20	0.01	0	0.01	0.01
TI02	0.09	0.04	0.15	0.04
P205	0.02	0.01	0.02	0.01
MNO	0.15	0.04	0.81	0.11
LOI	22.82	4.02	28.4	17.8
H20	2.8	0.6	3.7	2.2
C02	20.2	4.18	25.1	14.2
SUM	100.2	0.46	100.6	99.5
ppm				
Cr	1870	711.79	2480	750
Rb	9	2.24	10	5
Sr	147	94.18	250	5
Y	7	2.74	10	5
Zr	5	0	5	5
Nb	16	5.48	20	10

P N=4

wt.%	mean	std dev.	high	low
Si02	27.48	10.34	35.4	12.4
Al203	3.21	5.14	10.9	0.33
Fe203	8.94	3.5	14.1	6.57
Mg0	32.8	4.12	36.2	27
Ca0	3.37	2.82	6.61	0.78
Na20	0.09	0.02	0.12	0.06
K20	0.01	0.01	0.02	0.01
Ti02	0.24	0.38	0.8	0.03
P205	0.04	0.05	0.12	0.02
Mn0	0.11	0.05	0.17	0.04
LOI	23.28	10.7	37	11.9
H20	4.4	3.16	8	1.7
C02	17.9	15.02	35.9	1.1
SUM	99.92	0.92	100.6	98.6
ppm				
Cr	2100	1136.9	3200	620
Rb	6.25	2.5	10	5
Sr	78.75	82.3	20	5
Y	8.75	7.5	20	5
Zr	21.25	32.5	70	5
Nb	12.5	9.57	20	0

APPENDIX C-3: FACTOR ANALYSIS AND FACTOR PLOTS USING WHOLE ROCK ANALYSES FROM ROPES DEPOSIT

FACTOR ANALYSIS: NUMERICAL RESULTS

(19 VARiABLES)

SAS 14:57 MONDAY, JANUARY 27, 1986 1

VARIABLE	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
TRAVERSE	36	1.5000	1.2071	54.00	0	3.000
DISTANCE	36	102.9722	122.7019	3707.00	0	434.000
SIO2	36	46.6333	19.3686	1750.60	12.400	84.200
AL2O3	36	8.3761	7.1514	301.54	0.330	25.000
FE2O3	36	5.9003	2.1898	212.41	2.150	14.100
MGO	36	15.6097	10.7459	561.95	2.100	37.100
CAO	36	4.5697	5.9575	164.51	0.140	25.000
NA2O	36	0.1289	0.1112	4.64	0.060	0.750
K2O	36	1.7574	1.9370	63.26	0.009	6.350
TIO2	36	0.4364	0.3358	15.71	0.030	1.320
P2O5	36	0.1633	0.2941	5.88	0.010	1.580
MNO	36	0.0836	0.0736	3.01	0.010	0.360
LOI	36	12.9144	10.0795	464.92	3.160	38.100
H2O	36	3.0886	1.5618	111.19	0.090	8.000
CO2	36	9.3961	11.1773	338.26	0.090	37.100
SUM	36	99.3611	1.4790	3577.00	94.300	100.700
CR	36	746.9444	902.5307	26890.00	10.000	3200.000
RB	36	65.2778	62.1557	2350.00	5.000	200.000
SR	36	88.4722	127.2389	3185.00	5.000	530.000
Y	36	12.2222	12.5510	440.00	5.000	60.000
ZR	36	80.5556	90.4969	2900.00	5.000	410.000
NB	36	15.4167	8.1394	555.00	0	40.000

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CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / N = 36

	TRAVERSE	DISTANCE	SIO2	AL203	FE203	MGO	CAO	NA20	K20	TIO2	P205	MNO	LOI
TRAVERSE	1.00000 0.0000	0.57764 0.0002	-0.19702 0.2494	-0.36383 0.0259	0.01886 0.9131	0.36973 0.0265	0.13381 0.2701	-0.32340 0.0544	-0.45608 0.0052	-0.43157 0.0086	-0.36946 0.0266	0.14639 0.3943	0.30821 0.0674
DISTANCE	0.57764 0.0002	1.00000 0.0000	-0.18544 0.2739	-0.43634 0.0078	-0.10611 0.5379	0.53097 0.0009	0.03491 0.8395	-0.24196 0.1553	-0.46270 0.0045	-0.43963 0.0073	-0.30352 0.0719	-0.01214 0.9440	0.26719 0.1152
SIO2	-0.19702 0.2494	-0.18544 0.2739	1.00000 0.0000	0.41057 0.0129	-0.45811 0.0050	-0.78449 0.0001	-0.63981 0.0001	0.09030 0.6005	0.33039 0.0491	0.25299 0.1366	0.04226 0.8067	-0.62495 0.0001	-0.88244 0.0001
AL203	-0.36383 0.0259	-0.43634 0.0078	0.41057 0.0129	1.00000 0.0000	0.22823 0.1806	-0.65929 0.0001	-0.50724 0.0016	0.35637 0.0329	0.55278 0.0001	0.77860 0.0001	0.22504 0.1870	-0.27110 0.1098	-0.65543 0.0001
FE203	0.01886 0.9131	-0.10611 0.5379	-0.45811 0.0050	0.22823 0.1806	1.00000 0.0000	0.32515 0.0530	-0.06162 0.7211	0.24452 0.1507	0.06170 0.7207	0.39876 0.0160	0.09150 0.5956	0.24282 0.1536	0.12289 0.4752
MGO	0.36973 0.0265	0.53097 0.0009	-0.78449 0.0001	-0.65929 0.0001	0.32515 0.0530	1.00000 0.0000	0.32671 0.0518	-0.19192 0.2621	-0.63356 0.0001	-0.52596 0.0010	-0.24550 0.1490	0.40403 0.0145	0.77279 0.0001
CAO	0.13381 0.2701	0.03491 0.8395	-0.63981 0.0001	-0.50724 0.0016	-0.06162 0.7211	0.32671 0.0518	1.00000 0.0000	-0.22820 0.1807	-0.47496 0.0034	-0.48505 0.0027	-0.22373 0.1896	0.55795 0.0004	0.75339 0.0001
NA20	-0.32340 0.0544	-0.24196 0.1553	0.09030 0.6005	0.35637 0.0329	0.24452 0.1507	-0.19192 0.2621	-0.22820 0.1807	1.00000 0.0000	0.32942 0.0498	0.55013 0.0005	0.10274 0.5510	-0.06268 0.7165	-0.24115 0.1565
K20	-0.45608 0.0052	-0.46270 0.0045	0.33039 0.0491	0.55278 0.0001	0.06170 0.7207	-0.63356 0.0001	-0.47496 0.0034	0.32942 0.0498	1.00000 0.0000	0.80905 0.0001	0.51841 0.0012	-0.27366 0.1063	-0.60239 0.0001
TIO2	-0.43157 0.0086	-0.43963 0.0073	0.25299 0.1366	0.77860 0.0001	0.39876 0.0160	-0.52596 0.0010	-0.48505 0.0027	0.55013 0.0005	0.80905 0.0001	1.00000 0.0000	0.63580 0.0001	-0.31871 0.0592	-0.59484 0.0001
P205	-0.36946 0.0266	-0.30352 0.0719	0.04226 0.8067	0.22504 0.1870	0.09150 0.5956	-0.24550 0.1490	-0.22373 0.1896	0.10274 0.5510	0.51841 0.0012	0.63580 0.0001	1.00000 0.0000	-0.17167 0.3173	-0.30213 0.0733
MNO	0.14639 0.3943	-0.01214 0.9440	-0.62495 0.0001	-0.27110 0.1098	0.24282 0.1536	0.40403 0.0145	0.55795 0.0004	-0.06268 0.7165	-0.27366 0.1063	-0.31871 0.0592	-0.17167 0.3173	1.00000 0.0000	0.58276 0.0002
LOI	0.30821 0.0674	0.26719 0.1152	-0.88244 0.0001	-0.65543 0.0001	0.12289 0.4752	0.77279 0.0001	0.75339 0.0001	-0.24115 0.1565	-0.60239 0.0001	-0.59484 0.0001	-0.30213 0.0733	0.58276 0.0002	1.00000 0.0000
H20	-0.08934 0.6044	-0.08730 0.6127	-0.02427 0.8883	0.43610 0.0078	0.69344 0.0001	0.07917 0.6463	-0.46637 0.0041	0.30570 0.0696	0.30135 0.0735	0.60364 0.0001	0.32983 0.0495	-0.17327 0.3122	-0.35070 0.0360
CO2	0.31[illegible] 0.0[illegible]	0.24836 0.1431	-0.79736 0.0001	-0.65876 0.0001	-0.01668 0.9231	0.69116 0.0001	0.78790 0.0001	-0.26443 0.1191	-0.63029 0.0001	-0.67531 0.0001	-0.36014 0.0310	0.61615 0.0001	0.97961 0.0001
SUM	0.06491 0.7[illegible]	0.09582 0.5[illegible]	-0.35[illegible] 0.0427	-0.04546 0.7924	0.10121 0.5568	0.33216 0.0478	0.08077 0.6396	-0.01503 0.9307	0.04012 0.8164	0.08011 0.6424	0.13944 0.4173	-0.29223 0.0837	0.30663 0.0689
CR	0.45697 0.0053	0.29008 0.0861	-0.61549 0.0001	-0.67536 0.0001	0.22069 0.1959	0.80712 0.0001	0.37661 0.0235	-0.25846 0.1280	-0.63349 0.0001	-0.62525 0.0001	-0.33785 0.0439	0.43312 0.0083	0.70005 0.0001

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CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / N = 36

	TRAVERSE	DISTANCE	SIO2	AL2O3	FE2O3	MGO	CAO	NA2O	K2O	TIO2	P2O5	MNO	LOI
RB	-0.65636 [illegible]	-0.42593 0.0096	0.32914 0.0507	0.33968 0.0001	0.03596 0.3351	-0.60896 0.0001	-0.46034 0.0047	0.21150 0.2156	0.97316 0.0001	0.77312 0.0001	0.55869 0.0004	-0.29344 0.0824	-0.59868 0.0001
SR	0.22349 0.1907	0.10663 0.5359	-0.62424 0.0001	-0.51160 0.0014	-0.11299 0.5118	0.34299 0.0406	0.94263 0.0001	-0.21671 0.2043	-0.46180 0.0046	-0.45358 0.0055	-0.16941 0.3221	0.38183 0.0216	0.75622 0.0001
Y	-0.19756 0.2474	-0.19312 0.2591	-0.09265 0.5910	0.22936 0.1784	0.34260 0.0403	-0.13531 0.2793	-0.09031 0.6004	0.45471 0.0053	0.43560 0.0079	0.68911 0.0001	0.73261 0.0001	0.08073 0.5397	-0.20255 0.2361
ZR	-0.41536 0.0117	-0.41066 0.0129	0.22613 0.1949	0.52502 0.0001	0.14140 0.4107	-0.49608 0.0021	-0.42201 0.0104	0.19467 0.2509	0.51957 0.0001	0.82546 0.0001	0.56471 0.0001	-0.31016 0.0656	-0.53397 0.0008
NB	-0.45900 0.0050	-0.16348 0.3407	0.05519 0.6090	-0.01079 0.9502	-0.11037 0.5216	-0.10107 0.5575	-0.00580 0.9732	-0.13062 0.4494	0.00252 0.9884	0.02870 0.8680	0.21965 0.1930	-0.20293 0.2351	-0.06819 0.6927

	H2O	CO2	SUM	CR	RB	SR	Y	ZR	NB
TRAVERSE	-0.03956 [illegible]	0.31803 [illegible]	[illegible]	[illegible]	-0.65636 0.0053	0.22349 [illegible]	-0.19756 0.2474	-0.41594 0.0117	-0.45892 0.0050
DISTANCE	-0.03330 [illegible]	[illegible]	[illegible]	[illegible]	-0.42593 0.0096	0.10663 0.5356	-0.19312 0.2591	-0.41266 0.0129	-0.16749 0.3437
SIO2	-0.02427 0.8853	[illegible]	-0.33962 0.0427	[illegible] 0.0001	0.32914 0.0507	-0.62424 0.0001	-0.09265 0.5910	0.22613 0.1848	0.08819 0.6090
AL2O3	0.43910 0.0078	[illegible] 0.0001	[illegible]	[illegible] 0.0001	[illegible] 0.0001	-0.51142 0.0014	0.22936 0.1784	[illegible] 0.0001	-0.01079 0.9502
FE2O3	[illegible] 0.0001	-0.01653 0.9231	[illegible]	0.22049 [illegible]	0.03596 [illegible]	-0.11299 0.5113	0.36260 0.0408	0.16140 0.4107	-0.11037 0.5216
MGO	0.07917 [illegible]	[illegible]	[illegible]	[illegible] 0.0001	[illegible] 0.0001	0.34299 0.0406	-0.18531 0.2793	-0.49603 0.0021	-0.10107 0.5575
CAO	-0.46657 0.0041	[illegible] 0.0001	0.03177 [illegible]	0.37831 0.0235	-0.46034 0.0047	[illegible] 0.0001	-0.09031 0.6004	-0.42201 0.0104	-0.00580 0.9732
NA2O	0.34570 [illegible]	-0.26443 0.1191	[illegible]	-0.25960 [illegible]	0.21150 0.2156	-0.21671 0.2043	0.45671 0.0053	0.15467 0.2309	-0.13062 0.4484
K2O	[illegible]	[illegible] 0.0001	[illegible]	[illegible] 0.0001	[illegible] 0.0001	-0.46180 0.0046	0.43560 0.0079	[illegible] 0.0001	0.00252 0.9884
TIO2	[illegible] 0.0001	[illegible] 0.0001	[illegible] 0.5424	[illegible] 0.0001	[illegible] 0.0001	-0.45358 0.0055	[illegible] 0.0001	[illegible] 0.0001	0.02870 0.8680
P2O5	[illegible] 0.0495	-0.36013 0.0310	[illegible]	-0.33785 0.0435	[illegible]	-0.16981 0.3221	0.73261 0.0001	[illegible] 0.0001	0.21965 0.1980
MNO	[illegible] 0.3132	[illegible]	[illegible]	0.43312 0.0083	[illegible] 0.0924	0.38183 0.0216	0.08073 0.6397	-0.31016 0.0656	-0.20293 0.2351

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CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / N = 36

	H2O	CO2	SUM	CR	RB	SR	Y	ZR	NB
LOI	-0.35070 0.0360	0.97641 0.0001	0.30663 0.0689	0.70005 0.0001	-0.598[illegible]5 0.0001	0.75422 0.0001	-0.20255 0.2361	-0.53397 0.0008	-0.06819 0.6927
H2O	1.00000 0.0000	-0.51330 0.0014	0.17654 0.3030	-0.15092 0.3796	0.31379 0.0624	-0.45030 0.0059	0.38953 0.0189	0.43501 0.0080	-0.08963 0.6032
CO2	-0.51330 0.0014	1.00000 0.0000	0.20145 0.2339	0.69663 0.0001	-0.63020 0.0001	0.77151 0.0001	-0.25228 0.1377	-0.59699 0.0001	-0.07036 0.6834
SUM	0.17654 0.3030	0.20145 0.2339	1.00000 0.0000	0.27261 0.1050	0.11910 0.4890	0.21260 0.2132	-0.04058 0.8142	0.12515 0.4671	-0.08742 0.6114
CR	-0.15092 0.3796	0.69663 0.0001	0.27261 0.1050	1.00000 0.0000	-0.62698 0.0001	0.33280 0.0473	-0.28897 0.0874	-0.56764 0.0003	-0.18516 0.2796
RB	0.31379 0.0624	-0.63020 0.0001	0.11910 0.4890	-0.62698 0.0001	1.00000 0.0000	-0.43633 0.0078	0.39971 0.0157	0.84491 0.0001	0.03504 0.8392
SR	-0.45030 0.0059	0.77151 0.0001	0.21260 0.2132	0.33280 0.0473	-0.43633 0.0078	1.00000 0.0000	-0.09837 0.5681	-0.36895 0.0268	0.03926 0.8202
Y	0.38953 0.0189	-0.25228 0.1377	-0.04058 0.8142	-0.28897 0.0874	0.39971 0.0157	-0.09837 0.5681	1.00000 0.0000	0.63794 0.0001	-0.00932 0.9570
ZR	0.43501 0.0080	-0.59699 0.0001	0.12515 0.4671	-0.56764 0.0003	0.84491 0.0001	-0.36895 0.0268	0.63794 0.0001	1.00000 0.0000	0.11507 0.5039
NB	-0.08963 0.6032	-0.07036 0.6834	-0.08742 0.6114	-0.18516 0.2796	0.03504 0.8392	0.03926 0.8202	-0.00932 0.9570	0.11507 0.5039	1.00000 0.0000

INITIAL FACTOR METHOD: PRINCIPAL COMPONENTS

PRIOR COMMUNALITY ESTIMATES: ONE

EIGENVALUES OF THE CORRELATION MATRIX: TOTAL = 19.000000 AVERAGE = 1.000000

	1	2	3	4	5	6	7	8	9	10
EIGENVALUE	8.902213	3.131325	1.989480	1.296485	0.964461	0.659271	0.376537	0.549899	0.250691	0.189834
DIFFERENCE	5.770892	1.142950	0.691993	0.332045	0.105170	0.281734	0.026639	0.299208	0.060957	0.067890
PROPORTION	0.4685	0.1648	0.1047	0.0682	0.0508	0.0452	0.0303	0.0289	0.0132	0.0100
CUMULATIVE	0.4685	0.6333	0.7380	0.8062	0.8570	0.9022	0.9325	0.9615	0.9746	0.9846

	11	12	13	14	15	16	17	18	19
EIGENVALUE	0.121366	0.052973	0.036183	0.031236	0.022640	0.017019	0.010147	0.001130	0.000573
DIFFERENCE	0.068905	0.016797	0.002948	0.008596	0.005670	0.006873	0.009047	0.000557	
PROPORTION	0.0064	0.0028	0.0019	0.0016	0.0012	0.0009	0.0005	0.0001	0.0000
CUMULATIVE	0.9911	0.9939	0.9956	0.9973	0.9985	0.9994	0.9999	1.0000	1.0000

5 FACTORS WILL BE RETAINED BY THE NFACTOR CRITERION

FACTOR PATTERN

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5
SIO2	[illegible]	[illegible]	-0.04581	-0.30871	-0.16010
AL2O3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FE2O3	[illegible]	[illegible]	[illegible]	0.00168	0.07464
MGO	[illegible]	[illegible]	[illegible]	0.26785	0.09123
CAO	[illegible]	0.22714	[illegible]	-0.19955	[illegible]
NA2O	[illegible]	0.31077	-0.17763	-0.41719	[illegible]
K2O	0.31330	0.14326	[illegible]	-0.20750	0.26566
TIO2	[illegible]	[illegible]	[illegible]	-0.56374	-0.10550
P2O5	[illegible]	[illegible]	[illegible]	[illegible]	-0.34851
MNO	[illegible]	0.65049	[illegible]	-0.33075	0.13196
LOI	[illegible]	[illegible]	[illegible]	-0.02227	0.09076
H2O	[illegible]	[illegible]	[illegible]	0.15564	0.32673
CO2	[illegible]	[illegible]	[illegible]	-0.08778	0.05060
CR	[illegible]	[illegible]	-0.12067	0.14415	0.13354
RB	[illegible]	0.19509	[illegible]	-0.13272	0.35416
SR	[illegible]	[illegible]	[illegible]	-0.13767	-0.06396
Y	[illegible]	[illegible]	[illegible]	0.04262	-0.37549
ZR	[illegible]	[illegible]	0.30512	[illegible]	[illegible]
NB	[illegible]	[illegible]	[illegible]	[illegible]	-0.15150

VARIANCE EXPLAINED BY EACH FACTOR

FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

FINAL COMMUNALITY ESTIMATES: TOTAL = [illegible]

SIO2	AL2O3	FE2O3	MGO	CAO	NA2O	K2O	TIO2	P2O5	MNO
0.9[illegible]	0.8[illegible]	[illegible]	[illegible]	[illegible]	0.5…	0.92…	0.955270	0.881675	0.625201

LOI	H2O	CO2	CR	RB	SR	Y	ZR	NB
0.930384	0.83…	[illegible]	[illegible]	0.946785	0.837799	0.967101	0.965321	0.517825

INITIAL FACTOR METHOD: PRINCIPAL COMPONENTS

SQUARED MULTIPLE CORRELATIONS OF THE VARIABLES WITH EACH FACTOR

FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5
1.000000	1.000000	1.000000	1.000000	1.000000

STANDARDIZED SCORING COEFFICIENTS

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5
SIO2	0.07210	-0.22919	-0.03311	-0.00461	-0.14600
AL2O3	0.09322	0.02682	-0.21152	-0.27157	0.27134
FE2O3	0.00795	0.23713	-0.24673	0.00130	0.07719
MGO	-0.08287	0.12367	-0.18222	0.20657	0.08423
CAO	-0.05159	0.07254	0.25600	-0.15392	-0.05155
NA2O	0.04273	0.09925	-0.05923	-0.32179	-0.54255
K2O	0.09559	0.05552	0.11712	-0.15005	0.27544
TIO2	0.09762	0.13694	0.01629	-0.04916	-0.10939
P2O5	0.06151	0.14366	0.19851	0.36073	-0.05030
MNO	-0.05942	0.14387	0.04945	-0.24205	0.13670
LOI	-0.09925	0.11435	0.07192	-0.01717	0.08374
H2O	0.05464	0.16207	-0.28013	0.14318	0.03772
CO2	-0.10290	0.07409	0.11051	-0.06771	0.05247
CR	-0.09661	0.04792	-0.14125	0.11118	0.13846
RB	0.09459	0.05301	0.13277	-0.09465	0.36722
SR	-0.07309	0.06506	0.27204	-0.08305	-0.09741
Y	0.05125	0.21176	0.11595	0.06372	-0.38933
ZR	0.09111	0.11392	0.15344	0.15864	0.16316
NB	0.00909	-0.04255	0.16364	0.44585	-0.13634

FACTOR SCORES ROPES MINE WHOLEROCK DATA

OBS	SAMPLE	RKTYPE	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5
1	[illegible]	[illegible]	[illegible]	[illegible]	-0.0761	-0.2636	1.8669
2	[illegible]	[illegible]	[illegible]	[illegible]	-0.1697	-0.5171	1.0200
3	[illegible]	[illegible]	[illegible]	[illegible]	-0.3287	-0.2882	0.6939
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.3921
5	[illegible]	AS	1.0106	[illegible]	0.0651	[illegible]	-0.9615
6	[illegible]	AS	[illegible]	[illegible]	-0.9459	0.1797	-0.5612
7	[illegible]	AS	1.1270	1.5683	-1.2378	[illegible]	-4.6228
8	[illegible]	AS	[illegible]	[illegible]	[illegible]	[illegible]	-0.2559
9	[illegible]	AS	[illegible]	[illegible]	[illegible]	0.6430	-0.2735
10	[illegible]	AS	[illegible]	[illegible]	0.9120	1.9834	-0.0175
11	[illegible]	AS	[illegible]	[illegible]	0.1761	0.0663	0.5675
12	[illegible]	AS	[illegible]	[illegible]	-0.7122	-0.9101	0.3265
13	[illegible]	AS	[illegible]	[illegible]	[illegible]	-0.3010	[illegible]
14	[illegible]	AS	[illegible]	[illegible]	[illegible]	-0.2535	0.7795
15	[illegible]	AS	[illegible]	[illegible]	-0.1741	-0.1000	0.1812
16	[illegible]	AS	[illegible]	[illegible]	[illegible]	-0.2062	0.3216
17	[illegible]	AS	[illegible]	[illegible]	-0.3838	-0.5504	0.3616
18	[illegible]	AS	[illegible]	[illegible]	-0.0455	-0.9570	[illegible]
19	[illegible]	AS	[illegible]	[illegible]	-0.5865	1.2598	-1.5630
20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-0.9722
21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-0.1150	[illegible]
22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-0.7757	-0.6171
23	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-0.6136
24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-0.5580	-0.1216
25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-1.0120	0.1902
26	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-0.0214	-0.3923
27	[illegible]	[illegible]	[illegible]	[illegible]	-1.1221	1.3306	-0.2167
28	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-0.2115
29	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.2850	-0.3075
30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.5509	0.1005
31	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
32	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
33	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
34	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
35	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
36	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

FACTOR ANALYSIS: FACTOR PLOTS

(19 VARIABLES)

rock types plotted as:

A = quartz- sericite - chlorite rock

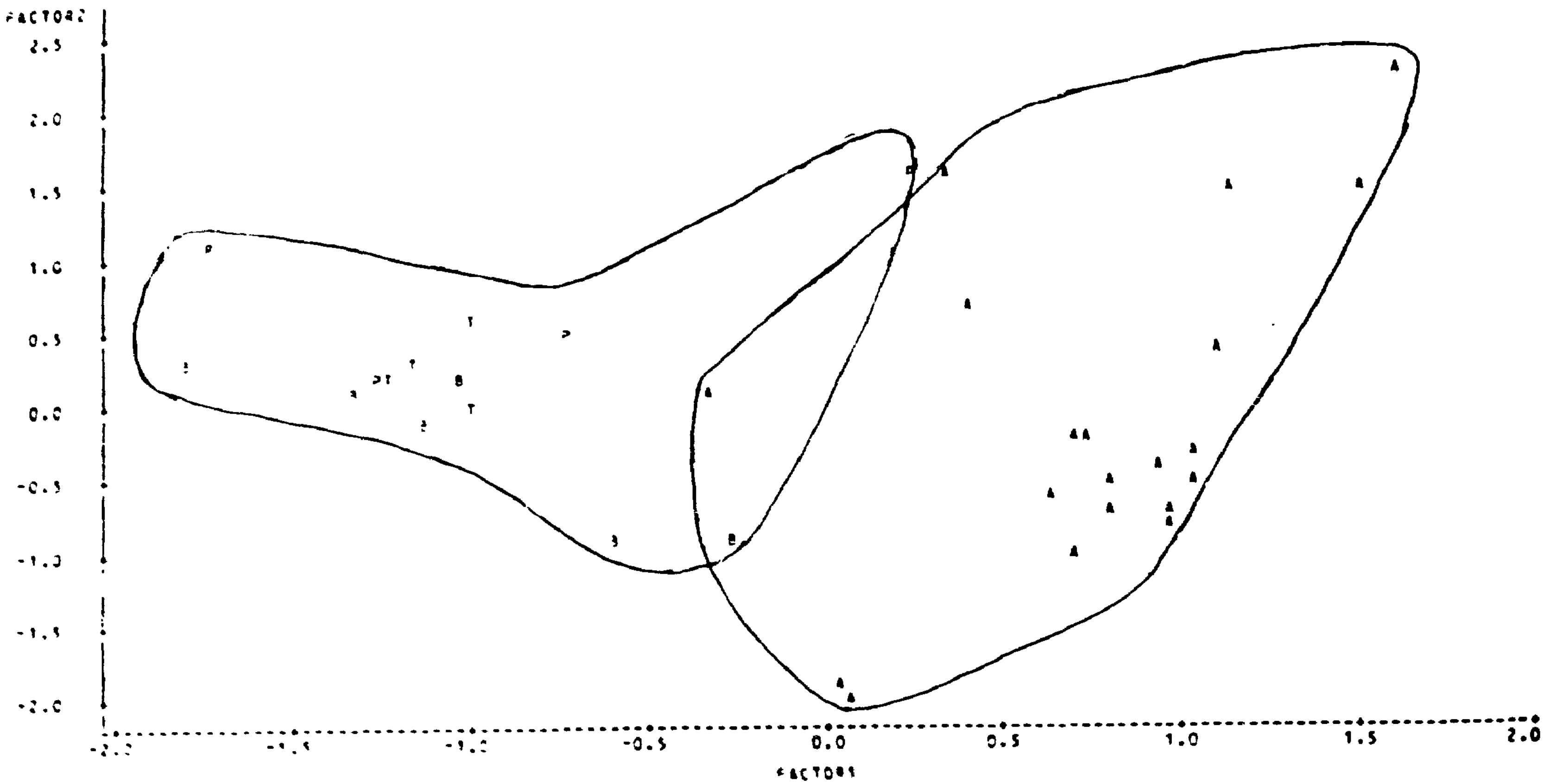
B = carbonate - quartz - chlorite rock

T = carbonate - talc rock

P = serpentinitic peridotite

FACTOR SCORES ROPES MINE WHOLEROCK DATA
FACTOR PLOTS ROPES MINE WHOLEROCK DATA   14:57 MONDAY, JANUARY 27, 1986   19

PLOT OF FACTOR2*FACTOR1   SYMBOL IS VALUE OF RKTYPE



NOTE: 2 OBS HIDDEN

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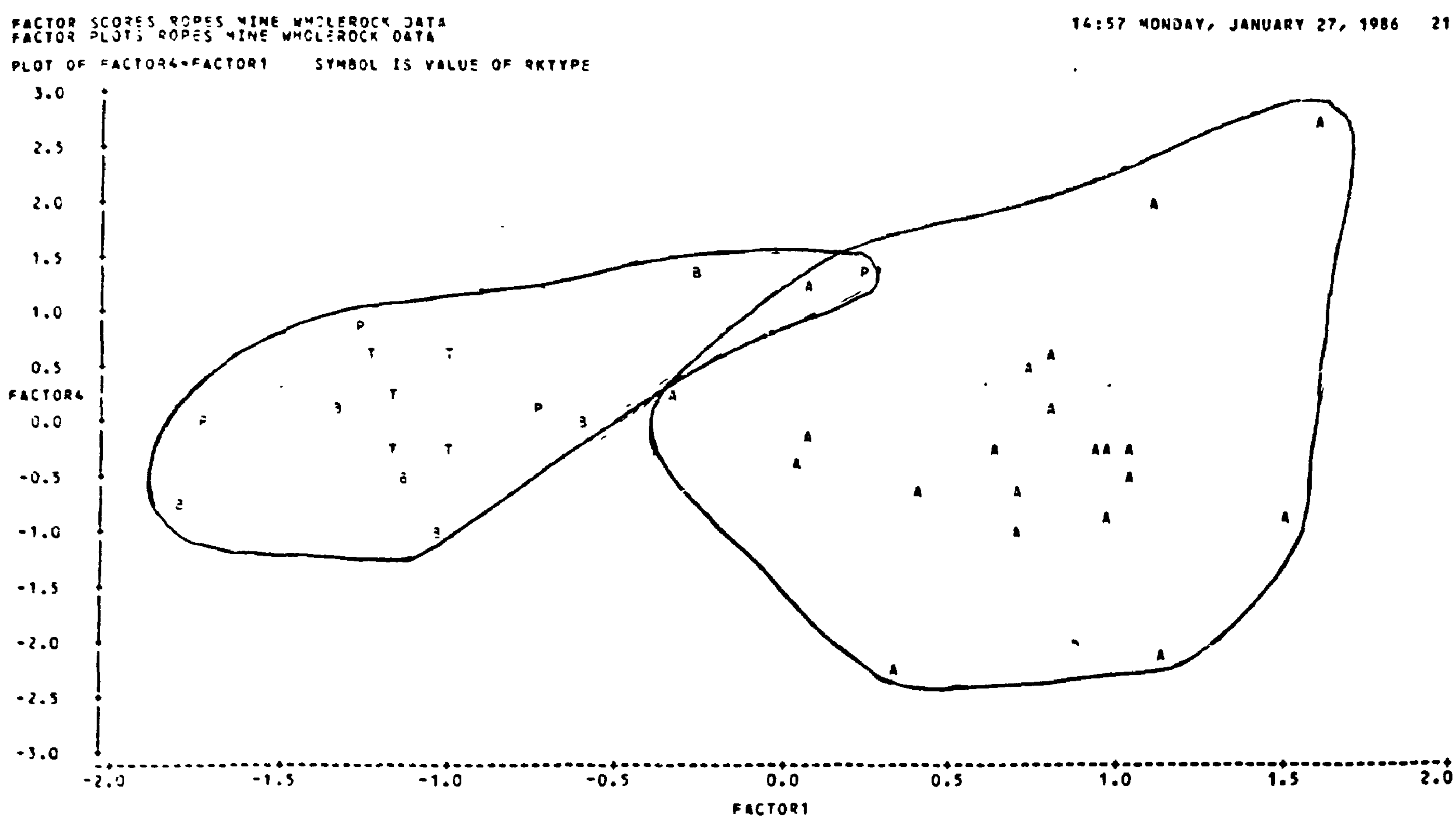
INITIAL FACTOR METHOD: PRINCIPAL COMPONENTS

STANDARDIZED SCORING COEFFICIENTS

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5
SIO2	0.11284	-0.25004	-0.12229	0.11279	0.00593
AL2O3	0.12552	0.09075	0.19403	0.25299	-0.46603
FE2O3	0.00790	0.34679	-0.19598	0.11424	-0.29292
MGO	-0.11571	0.15996	-0.31290	-0.12593	0.15562
CAO	-0.11607	0.01752	0.36435	0.02261	-0.02444
NA2O	0.05161	0.14655	0.10940	0.55886	0.36619
K2O	0.17523	0.07021	0.36823	-0.05668	-0.18754
TIO2	0.12271	0.13726	0.17355	-0.05713	0.14526
P2O5	0.07116	0.11553	0.26560	-0.74025	0.34732
MNO	-0.07313	0.16709	[illegible]	0.20472	-0.37504
LOI	-0.14556	0.09966	0.10635	-0.02585	0.08258
H2O	0.37002	0.24740	-0.15275	-0.04455	-0.09903
CO2	-0.14931	0.04055	0.14290	0.02950	0.09167


FACTOR SCORES ROPES MINE WHOLEROCK DATA
FACTOR PLOTS ROPES MINE WHOLEROCK DATA
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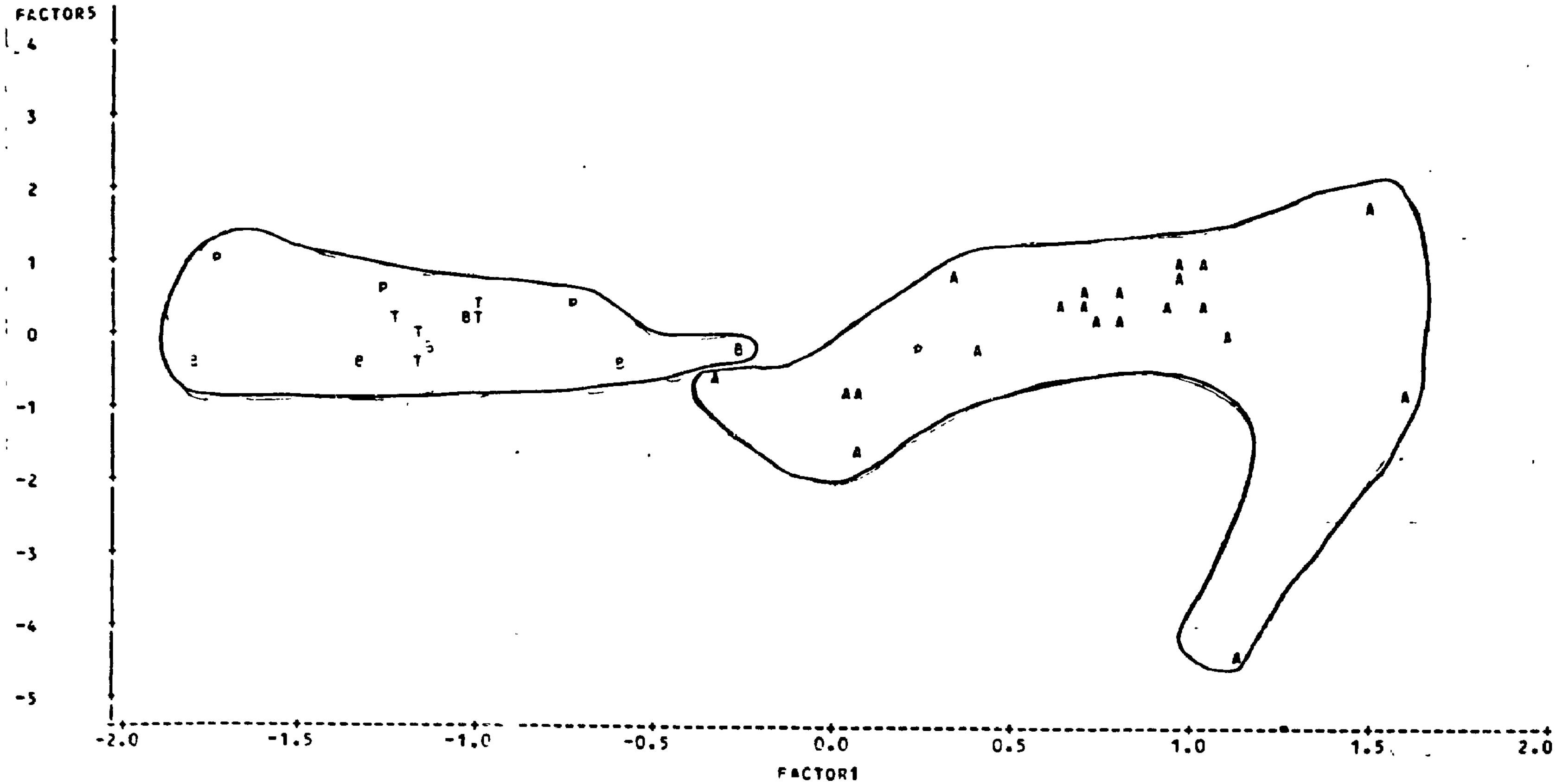
PLOT OF FACTOR4*FACTOR1 SYMBOL IS VALUE OF RKTYPE
FACTOR4
FACTOR1
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0

FACTOR SCORES ROPES MINE WHOLEROCK DATA
FACTOR PLOTS ROPES MINE WHOLEROCK DATA 14:57 MONDAY, JANUARY 27, 1986 22

PLOT OF FACTOR5*FACTOR1 SYMBOL IS VALUE OF PKTYPE



FACTOR SCOPES ROPES MINE WHOLEROCK DATA
FACTOR PLOT: ROPES MINE WHOLEROCK DATA

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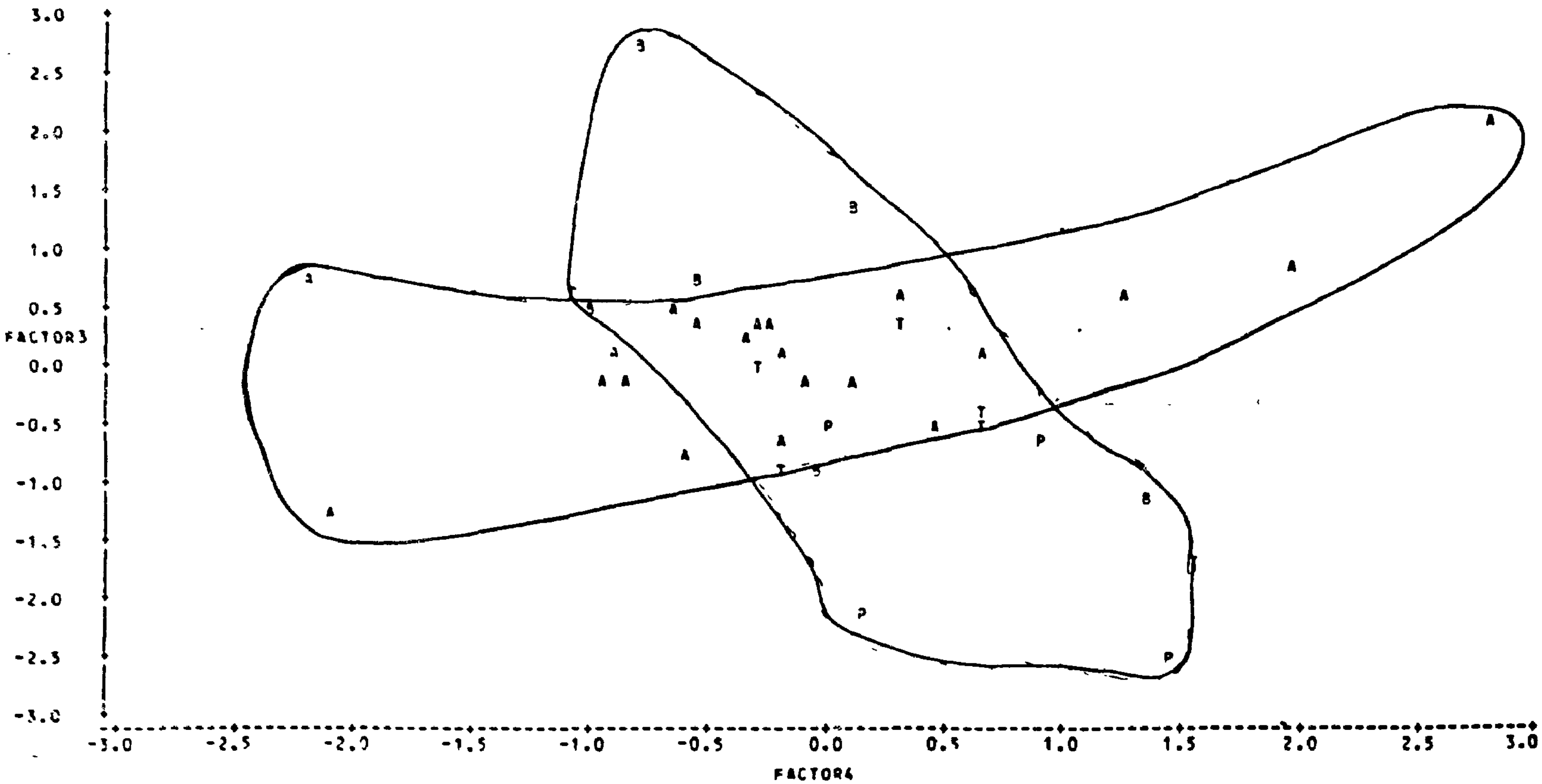
PLOT OF FACTOR3*FACTOR4 SYMBOL IS VALUE OF RKTYPE



FACTOR ANALYSIS: NUMERICAL RESULTS

(13 VARIABLES)

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VARIABLE	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
TRAVERSE	36	1.5000	1.2071	54.000	0	3.0000
DISTANCE	36	102.9722	122.7013	3707.000	0	434.0000
SIO2	36	48.6333	13.3535	1750.800	12.4000	94.2000
AL2O3	36	8.3761	7.1514	301.540	0.3300	25.0000
FE2O3	36	5.9003	2.1392	212.410	2.1500	14.1000
MGO	36	15.6097	10.7497	561.950	2.1000	37.1000
CAO	36	4.5427	5.9575	154.510	0.1400	25.0000
NA2O	36	0.1233	0.1112	4.440	0.0600	0.7500
K2O	36	1.7574	1.9570	63.265	0.0090	6.3500
TIO2	36	0.4364	0.3359	15.710	0.0300	1.3200
P2O5	36	0.1633	0.2941	5.880	0.0100	1.5800
MNO	36	0.0836	0.0736	3.010	0.0100	0.3600
LOI	36	12.9144	10.0795	464.920	3.1600	38.1000
H2O	36	3.0384	1.5519	111.190	0.0900	9.0000
CO2	36	9.3951	11.1773	338.260	0.0900	37.1000

CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / N = 36

	TRAVERSE	DISTANCE	SIO2	AL2O3	FE2O3	MGO	CAO	NA2O	K2O	TIO2	P2O5	MNO	LOI
TRAVERSE	1.00000 0.0000	0.57766 0.0002	-0.19702 0.2494	-0.36883 0.0269	0.01836 0.9131	0.36973 0.0265	0.18881 0.2701	-0.32360 0.0544	-0.45605 0.0052	-0.43157 0.0085	-0.36946 0.0266	0.14639 0.3943	0.30821 0.0674
DISTANCE	0.57766 0.0002	1.00000 0.0000	-0.18566 0.2789	-0.43634 0.0078	-0.10611 0.5379	0.53097 0.0009	0.03491 0.8395	-0.24186 0.1553	-0.46270 0.0045	-0.43963 0.0073	-0.30352 0.0719	-0.01216 0.9440	0.26719 0.1152
SIO2	-0.19702 0.2494	-0.18566 0.2789	1.00000 0.0000	0.41057 0.0129	-0.45811 0.0050	-0.78469 0.0001	-0.63961 0.0001	0.09030 0.6005	0.33039 0.0491	0.25259 0.1366	0.04226 0.8067	-0.62495 0.0001	-0.88266 0.0001
AL2O3	-0.36883 0.0269	-0.43634 0.0078	0.41057 0.0129	1.00000 0.0000	0.22823 0.1806	-0.65929 0.0001	-0.50726 0.0016	0.35637 0.0329	0.85279 0.0001	0.77860 0.0001	0.22506 0.1870	-0.27110 0.1098	-0.65563 0.0001
FE2O3	0.01836 0.9131	-0.10611 0.5379	-0.45811 0.0050	0.22823 0.1806	1.00000 0.0000	0.32515 0.0530	-0.06162 0.7211	0.24452 0.1507	0.06170 0.7207	0.39876 0.0160	0.09150 0.5955	0.24282 0.1536	0.12289 0.4752

CORRELATION COEFFICIENTS / PROB > |R| UNDER H0:RHO=0 / N = 36

	TRAVERSE	DISTANCE	SIO2	AL2O3	FE2O3	MGO	CAO	NA2O	K2O	TIO2	P2O5	MNO	LOI
MGO	0.36973 0.0265	0.53097 0.0009	-0.78449 0.0001	-0.65929 0.0001	0.32515 0.0530	1.00000 0.0000	0.32671 0.0518	-0.19192 0.2621	-0.63356 0.0001	-0.52596 0.0010	-0.24550 0.1490	0.40403 0.0145	0.77279 0.0001
CAO	0.18931 0.2701	0.03491 0.8398	-0.63961 0.0001	-0.50724 0.0016	-0.06162 0.7211	0.32671 0.0518	1.00000 0.0000	-0.22820 0.1807	-0.47496 0.0034	-0.48505 0.0027	-0.22373 0.1896	0.55795 0.0004	0.75339 0.0001
NA2O	-0.32340 0.0544	-0.24196 0.1553	0.09030 0.6005	0.35637 0.0329	0.24652 0.1507	-0.19192 0.2621	-0.22820 0.1807	1.00000 0.0000	0.32942 0.0498	0.55013 0.0005	0.10274 0.5510	-0.06268 0.7165	-0.24115 0.1565
K2O	-0.45608 0.0052	-0.46270 0.0045	0.33039 0.0491	0.85278 0.0001	0.06170 0.7207	-0.63356 0.0001	-0.47496 0.0034	0.32942 0.0498	1.00000 0.0000	0.80905 0.0001	0.51841 0.0012	-0.27366 0.1063	-0.60239 0.0001
TIO2	-0.43157 0.0035	-0.43943 0.0073	0.25299 0.1366	0.77860 0.0001	0.39876 0.0160	-0.52596 0.0010	-0.48505 0.0027	0.55013 0.0005	0.80905 0.0001	1.00000 0.0000	0.63550 0.0001	-0.31871 0.0582	-0.59484 0.0001
P2O5	-0.36946 0.0266	-0.30352 0.0719	0.04226 0.8067	0.22506 0.1870	0.09150 0.5956	-0.24550 0.1490	-0.22373 0.1896	0.10274 0.5510	0.51841 0.0012	0.63550 0.0001	1.00000 0.0000	-0.17147 0.3173	-0.30213 0.0733
MNO	0.14639 0.3943	-0.01216 0.9440	-0.62495 0.0001	-0.27110 0.1098	0.24282 0.1536	0.40403 0.0145	0.55795 0.0004	-0.06268 0.7165	-0.27366 0.1063	-0.31871 0.0582	-0.17147 0.3173	1.00000 0.0000	0.58276 0.0002
LOI	0.30821 0.0674	0.26719 0.1152	-0.88244 0.0001	-0.65543 0.0001	0.12289 0.4752	0.77279 0.0001	0.75339 0.0001	-0.24115 0.1565	-0.60239 0.0001	-0.59484 0.0001	-0.30213 0.0733	0.58276 0.0002	1.00000 0.0000
H2O	-0.08934 0.6044	-0.00330 0.9847	-0.02427 0.9853	0.43610 0.0078	0.69346 0.0001	0.07917 0.6463	-0.46637 0.0041	0.30570 0.0698	0.30195 0.0735	0.60364 0.0001	0.32983 0.0495	-0.17327 0.3122	-0.35070 0.0360
CO2	0.31800 0.0588	0.24696 0.1431	-0.79736 0.0001	-0.68476 0.0001	-0.01668 0.9231	0.69116 0.0001	0.78790 0.0001	-0.26443 0.1191	-0.63028 0.0001	-0.67531 0.0001	-0.36016 0.0310	0.61615 0.0001	0.97941 0.0001

	H2O	CO2
TRAVERSE	-0.08934 0.6044	0.31800 0.0588
DISTANCE	-0.00330 0.9847	0.24696 0.1431
SIO2	-0.02427 0.8853	-0.79736 0.0001
AL2O3	0.43610 0.0078	-0.68476 0.0001
FE2O3	0.69346 0.0001	-0.01668 0.9231
MGO	0.07917 0.6463	0.69116 0.0001
CAO	-0.46637 0.0041	0.78790 0.0001

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CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / N = 36

	H2O	CO2
NA2O	0.30570 0.0698	-0.26463 0.1191
K2O	0.30125 0.0735	-0.63028 0.0001
TIO2	0.50364 0.0031	-0.67531 0.0001
P2O5	0.32933 0.0495	-0.36016 0.0310
MNO	-0.17327 0.3122	0.61615 0.0001
LOI	-0.35070 0.0360	0.97961 0.0001
H2O	1.00000 0.0000	-0.51330 0.0014
CO2	-0.51330 0.0014	1.00000 0.0000

INITIAL FACTOR METHOD: PRINCIPAL COMPONENTS

PRIOR COMMUNALITY ESTIMATES: ONE

EIGENVALUES OF THE CORRELATION MATRIX: TOTAL = 13.000000 AVERAGE = 1.000000

	1	2	3	4	5	6	7
EIGENVALUE	6.365515	2.562305	1.259046	0.966344	0.707714	0.445025	0.38372[illegible]
DIFFERENCE	3.803213	1.303258	0.292702	0.258630	0.262689	0.061304	0.199702
PROPORTION	0.4897	0.1971	0.0968	0.0743	0.0544	0.0342	0.0295
CUMULATIVE	0.4897	[illegible]	[illegible]	0.8579	0.9124	0.9466	0.9761

	8	9	10	11	12	13
EIGENVALUE	0.184019	0.067544	0.031121	0.023115	0.003442	0.001086
DIFFERENCE	0.116475	0.036424	0.008006	0.019673	0.002356	
PROPORTION	0.0142	[illegible].0052	0.0024	0.0018	0.0003	0.0001
CUMULATIVE	0.9903	0.9955	0.9979	0.9997	0.9999	1.0000

5 FACTORS WILL BE RETAINED BY THE MINEIGEN CRITERION

FACTOR PATTERN

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5
SIO2	[illegible]	[illegible]	-0.15396	0.10899	0.00420
AL2O3	[illegible]	[illegible]	0.23170	0.24447	-0.32982
FE2O3	[illegible]	[illegible]	-0.24675	0.11040	-0.20022
MGO	-0.75247	[illegible]	-0.4[illegible]277	-0.12174	0.11014
CAO	-0.7633[illegible]	0.05003	[illegible]	0.02185	-0.01780
NA2O	[illegible]	0.37546	0.1332[illegible]	[illegible]	[illegible]
K2O	[illegible]	0.17790	0.47543	[illegible]	-0.13272
TIO2	[illegible]	0.44495	0.22481	[illegible]	0.10279
P2O5	[illegible]	0.29[illegible]	0.31049	[illegible]	0.24581
MNO	[illegible]	[illegible]	[illegible]	0.19[illegible]	-0.26542
LOI	-0.92657	[illegible]	[illegible]	-0.02498	0.05844
H2O	[illegible]	[illegible]	-0.4461[illegible]	-0.08174	-0.0693[illegible]
CO2	-0.[illegible]5173	[illegible]	0.20761	0.02351	0.05780

VARIANCE EXPLAINED BY EACH FACTOR

FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5
6.365515	[illegible]	[illegible]	[illegible]	[illegible]

FINAL COMMUNALITY ESTIMATES: TOTAL = 11.[illegible]

SIO2	AL2O3	FE2O3	MGO	CAO	NA2O	K2O	TIO2	P2O5	MNO	LOI	H2O	CO2
0.961982	0.934324	0.995181	0.921257	0.797120	0.992831	0.880624	0.963909	0.964054	0.727474	0.945075	0.912308	0.963838

SQUARED MULTIPLE CORRELATIONS OF THE VARIABLES WITH EACH FACTOR

FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5
1.000000	1.000000	1.000000	1.000000	1.000000

SAS

INITIAL FACTOR METHOD: PRINCIPAL COMPONENTS

STANDARDIZED SCORING COEFFICIENTS

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	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5
SIO2	0.11284	-0.25004	-0.12229	0.11279	0.00593
AL2O3	0.12552	0.09075	0.18403	0.25299	-0.46603
FE2O3	0.00790	0.34479	-0.19590	0.11626	-0.28292
MGO	-0.11371	0.15994	-0.31790	-0.12593	0.15562
CAO	-0.11697	0.01952	0.36435	0.02261	-0.02644
NA2O	0.05157	0.16653	0.10980	0.55884	0.36619
K2O	0.17523	0.07021	0.34423	-0.05968	-0.18754
TIO2	0.12771	0.13226	0.17355	-0.05713	0.14524
P2O5	0.07115	0.11353	0.26540	-0.74023	0.34732
MNO	-0.09313	0.16709	0.2[illegible]	0.20472	-0.37506
LOI	-0.16550	0.09964	0.10635	-0.02585	0.08258
H2O	0.37622	0.24740	-0.15275	-0.08455	-0.09502
CO2	-0.16951	0.04055	0.14490	0.02950	0.09167

FACTOR SCORES ROPES MINE WHOLEROCK DATA

OBS	SAMPLE	RKTYPE	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5
1	RISO-14	AN	1.3023	1.7213	0.7647	0.0339	-1.3423
2	RISO-15	AN	1.0065	-0.0292	0.3264	0.1944	-0.6785
3	RISO-19	AN	0.9446	-0.2469	0.5097	0.2596	-0.3649
4	RISO-22	AN	-0.0662	1.4514	2.4435	1.1781	-1.8212
5	RISO-16	AS	1.0957	1.2360	1.2675	-4.1754	2.2559
6	RISO-48	AS	-0.3505	-0.1924	0.2234	-0.0868	-0.4012
7	RISO-18	AS	1.3099	1.5906	0.2347	3.2969	4.0934
8	RISO-47	AS	0.2440	0.1303	0.7373	0.1027	-0.8090
9	RS16-659	AS	0.8059	0.1440	-0.5646	-0.0676	-0.5718
10	RISO-30	AS	0.5579	0.3234	0.3319	-1.9336	0.3630
11	RISO-27	AS	0.7994	-0.4171	-0.2688	0.1304	-0.5335
12	RISO-44	AS	0.7464	-0.0103	-0.4935	0.1704	-0.5568
13	RS16-750	AS	0.5903	-0.5123	0.4270	0.4224	-0.3301
14	RS26-126	AS	1.0601	-0.5905	0.4632	0.0690	-0.2319
15	RS26-145	AS	0.9219	-0.2172	-0.1331	0.0562	-0.4611
16	RISO-32	AS	0.7189	-0.3430	-0.7050	0.1481	-0.2736
17	RISO-43	AS	1.0362	-0.6754	0.6714	-0.0260	-0.1665
18	RS16-786	AS	0.7731	-1.0102	0.0780	0.4074	-0.2670
19	RISO-25	AS	0.2417	-1.3910	-0.0973	0.4574	0.5155
20	RISO-62	AS	0.2424	-2.0257	-0.0841	0.1603	0.2861
21	RISO-41	AS	0.2471	-2.1106	-0.4970	0.0056	0.3005
22	RS26-166	BC	-2.0051	-0.2561	2.1877	-0.0727	0.4065
23	RS16-42	B	-1.3620	-0.3359	0.4801	-0.2911	0.4884
24	RISO-49	B	-1.0703	-0.3446	0.3917	0.0251	0.1398
25	RS26-113	B	-1.0844	0.0914	0.3629	0.4966	-0.6331
26	RS16-291	E	-0.4833	-0.9120	-0.9159	0.0546	1.0154
27	RS-16-16	E	-0.1312	-0.6471	-2.0131	-0.4420	0.3444
28	RS16-220	T	-1.2617	0.2008	-0.0263	-0.1324	0.5056
29	RS26-191	T	-1.1744	0.1536	0.1018	-0.0709	0.2170
30	RS16-477	T	-1.2052	0.1732	-0.2932	-0.0695	0.2294
31	RISO-45	T	-1.1090	0.1155	0.0851	0.0416	-0.2463
32	RISO-50	T	-0.8478	0.6861	-0.4551	0.2682	-0.7375
33	RISO-51	P	-1.7736	0.9590	0.0237	-0.0175	0.0785
34	RS26-259	P	-1.2495	0.2152	-0.5838	-0.2540	0.0347
35	RISO-46	P	-0.6488	0.6467	-2.0210	-0.2041	0.1597
36	RS16-540	P	0.3335	2.4632	-2.7500	-0.1779	-1.1776

FACTOR ANALYSIS: FACTOR PLOTS

(13 VARIABLES)

rock types plotted as:

A = quartz - sericite - chlorite rock

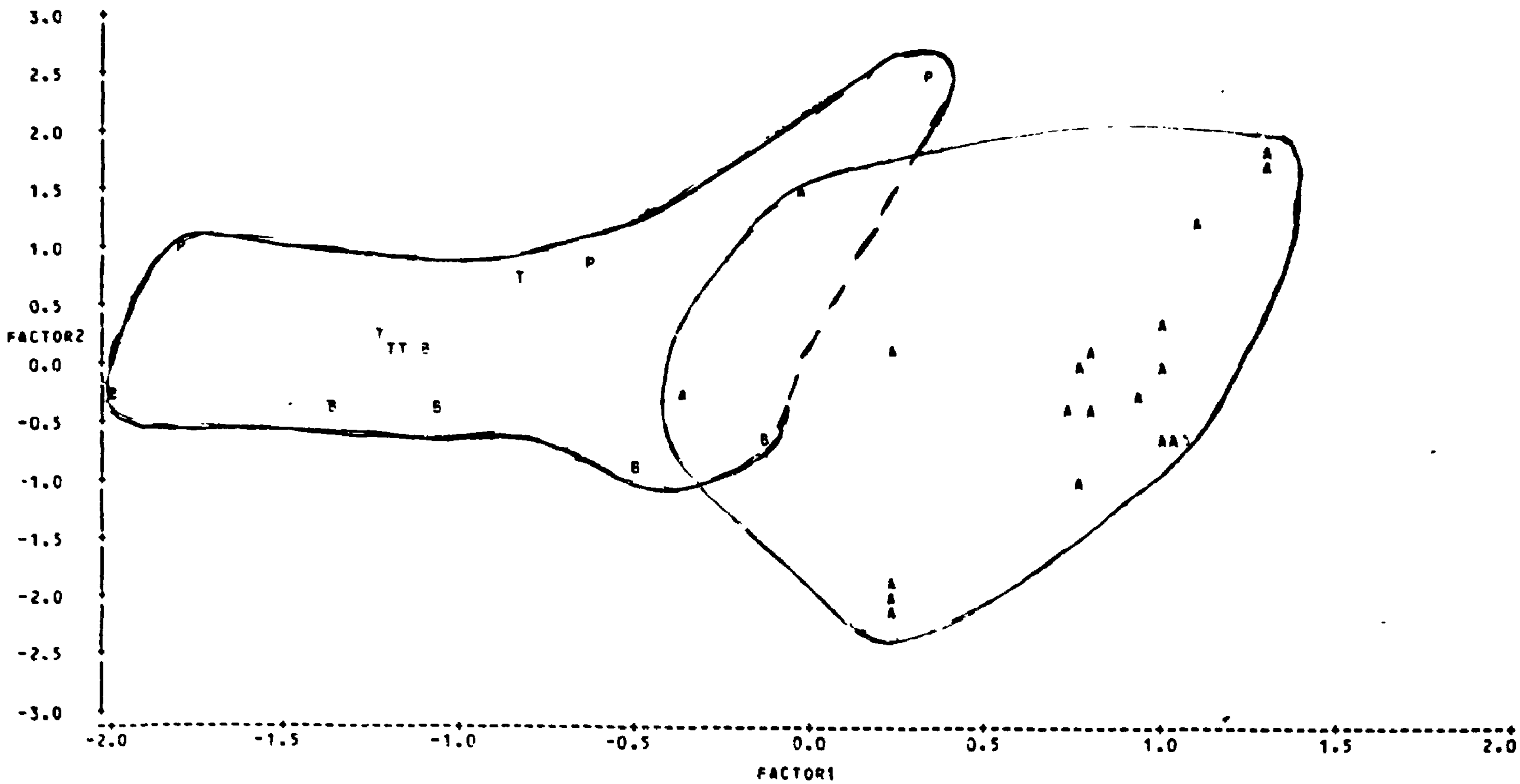
B = carbonate - quartz - chlorite rock

T = carbonate - talc rock

P = serpentinitic peridotite

FACTOR SCORES ROPES MINE WHOLEROCK DATA
FACTOR PLOTS ROPES MINE WHOLEROCK DATA 15:19 MONDAY, JANUARY 27, 1986 18

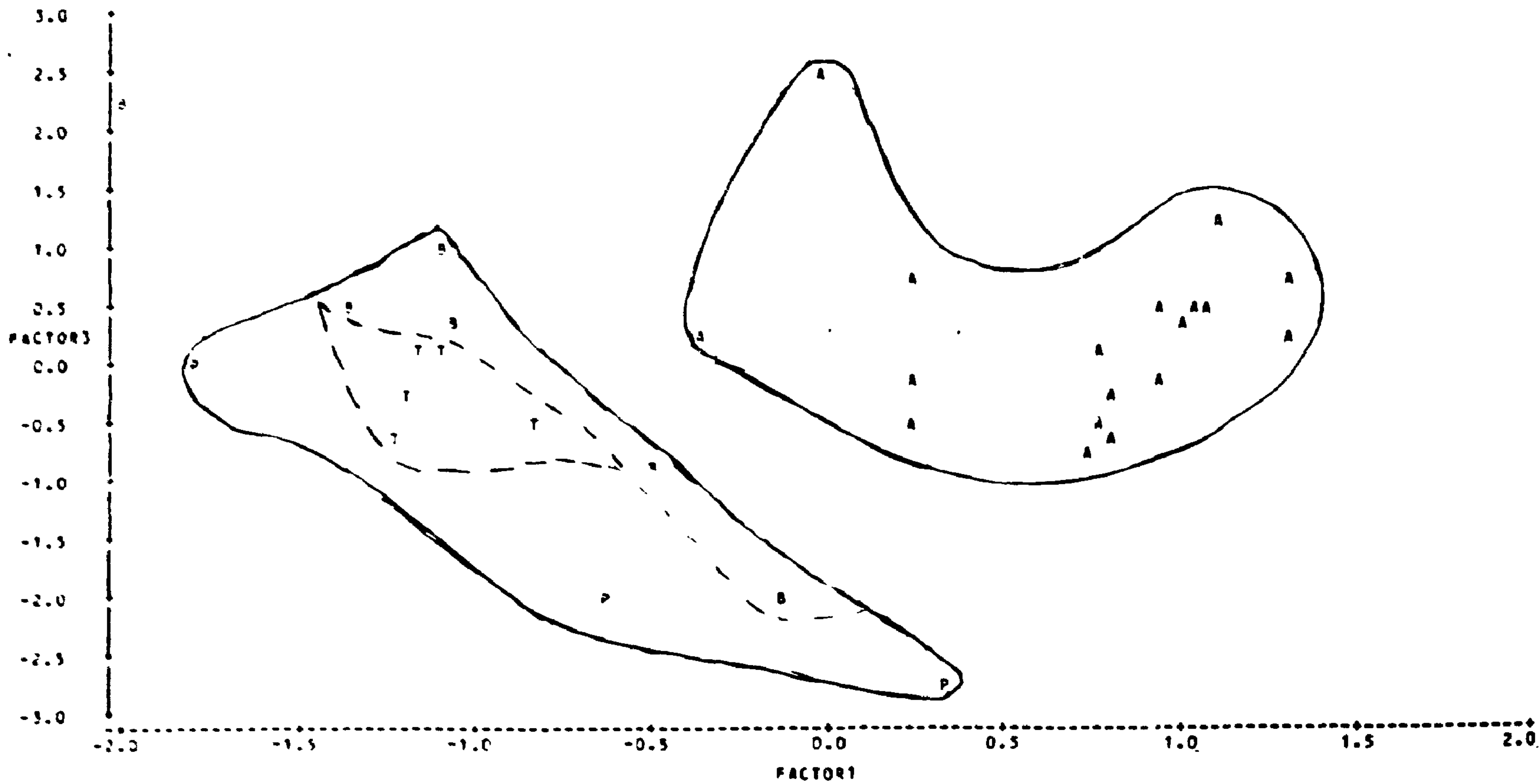
PLOT OF FACTOR2*FACTOR1 SYMBOL IS VALUE OF RKTYPE



NOTE: 3 OBS HIDDEN

FACTOR SCORES ROPES MINE WHOLEROCK DATA 15:19 MONDAY, JANUARY 27, 1986 19
FACTOR PLOTS ROPES MINE WHOLEROCK DATA

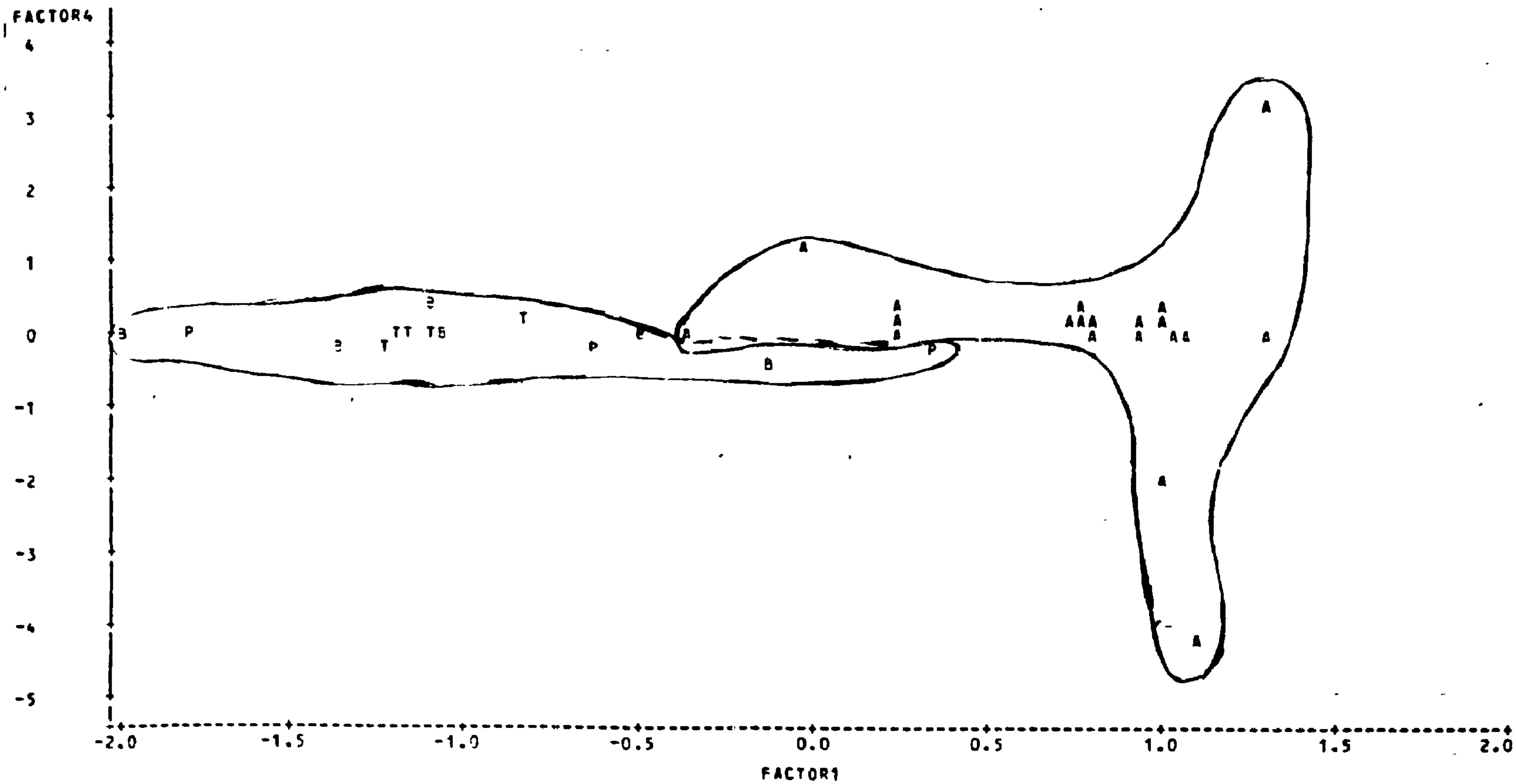
PLOT OF FACTOR3*FACTOR1 SYMBOL IS VALUE OF RKTYPE



NOTE: 4 OBS HIDDEN

FACTOR SCORES ROPES MINE WHOLEROCK DATA
FACTOR PLOTS ROPES MINE WHOLEROCK DATA   15:19 MONDAY, JANUARY 27, 1986   20

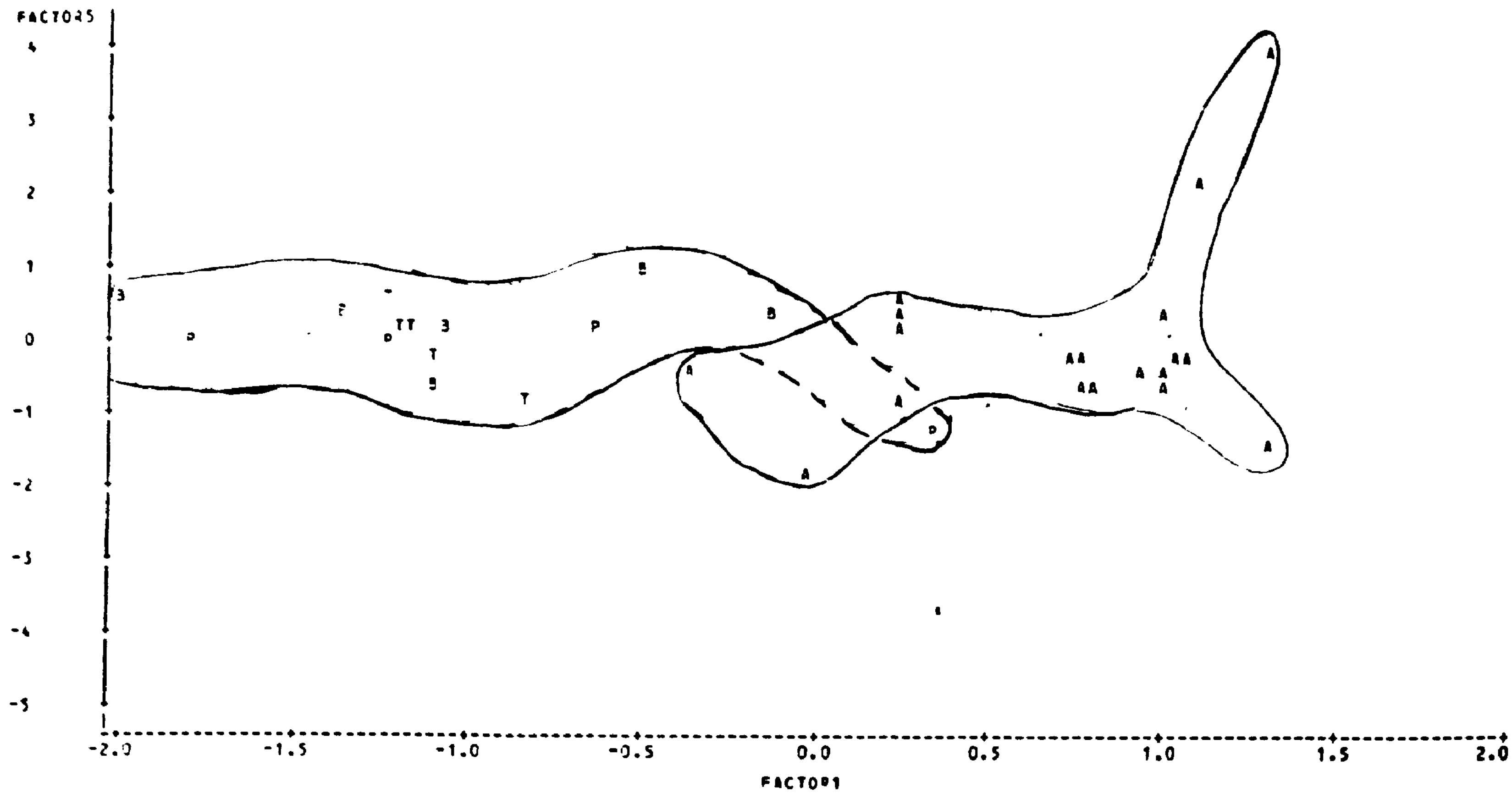
PLOT OF FACTOR4*FACTOR1   SYMBOL IS VALUE OF RKTYPE



NOTE: 2 OBS HIDDEN

FACTOR SCORES ROPES MINE WHOLEROCK DATA
FACTOR PLOTS ROPES MINE WHOLEROCK DATA   15:19 MONDAY, JANUARY 27, 1986   21

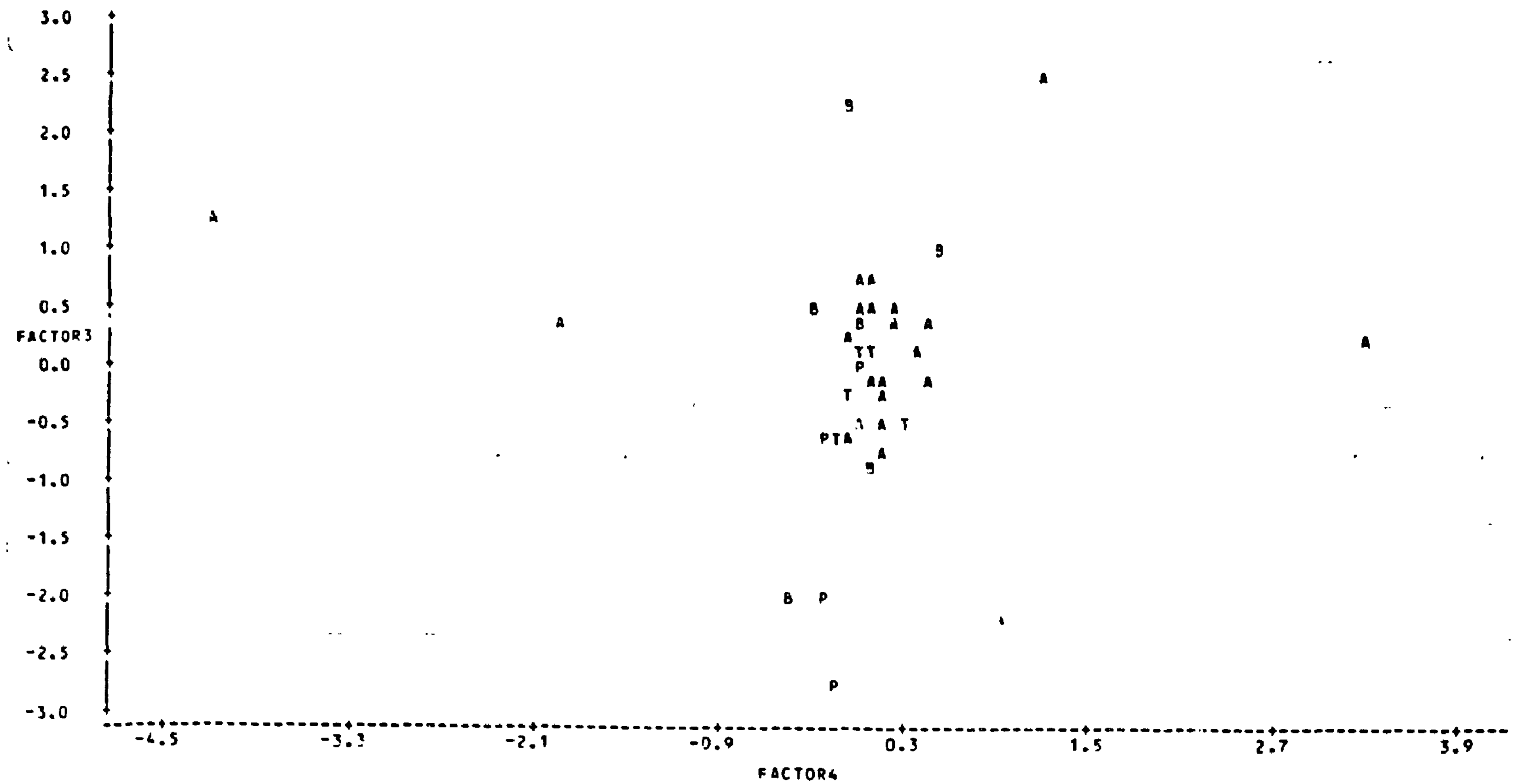
PLOT OF FACTOR5*FACTOR1   SYMBOL IS VALUE OF RKTYPE



NOTE: 2 OBS HIDDEN

FACTOR SCORES ROPES MINE WHOLEROCK DATA
FACTOR PLOTS ROPES MINE WHOLEROCK DATA

PLOT OF FACTOR3*FACTOR4 SYMBOL IS VALUE OF RKTYPE



APPENDIX D-1: 21 ELEMENT ICP ANALYSES

PLUS Au, Ag, As, Sb, Bi, AND Hg FROM ROPES DEPOSIT

rock type code:

A = quartz - sericite - chlorite rock

B = carbonate - quartz - chlorite rock

SAMPLE #	ROCK TYPE	Au	Mo	W
RC-40	A	1.37	3	5
RC-150	B	0.34	0.5	5
RC-200	A	0.34	2	5
RC-360	B	0.34	0.5	5
RC-500	A	6.34	0.5	5
RC-650	A	0.51	12	5
RC-700	A	0.68	10	25
RC-870	B	9.26	20	20
RC-1145	B	2.40	0.5	5
RC-1375	A	2.74	33	5
RC-1520	A	1.78	10	5
RC-1675	A	4.80	2	5
RC-1845	A	5.14	0.5	5
RC-1875	A	6.17	10	5
RC-1925	A	3.77	1	5
RC-2150	A	9.26	3	5
RC-2390	B	0.51	52	5
RC-2470	A	4.80	31	5
RC-2530	A	15.77	7	15
RC-2630	B	2.74	8	5
RC-2645	A	8.91	20	5
RC-2755	B	0.34	2	5
RC-2770	A	4.46	0.5	15
RC-2785	A	2.40	16	5
RC-2815	A	7.88	53	5
RC-2855	A	2.06	1	5
RC-2870	A	1.88	4	5
RC-2875	B	24.68	1	5
RC-3889	A	10.29	51	15
RC-3922	A	6.17	10	5
RC-3934	A	1.51	2	5
RC-3938	B	1.03	0.5	5
RC-3959	A	16.11	26	15
RC-4200	A	2.74	0.5	5
RC-4225	B	0.34	0.5	5
RC-4245	A	1.37	4	5
RC-4315	A	2.40	1	5
RC-4410	B	1.71	3	5

SAMPLE #	Zn	P	Pb	Cb
RC-40	50	650	16	14
RC-150	34	125	12	65
RC-200	50	960	12	15
RC-360	49	810	14	10
RC-500	480	145	6	46
RC-650	70	830	8	18
RC-700	40	840	14	16
RC-870	350	645	22	30
RC-1145	62	75	8	56
RC-1375	97	1750	16	25
RC-1520	54	585	14	26
RC-1675	24	425	12	10
RC-1845	52	1230	22	15
RC-1875	56	880	20	14
RC-1925	40	850	20	17
RC-2150	92	1030	16	19
RC-2390	14	10	10	31
RC-2470	270	945	12	38
RC-2530	103	1010	76	25
RC-2630	45	490	12	17
RC-2645	36	390	12	14
RC-2755	48	25	14	59
RC-2770	56	1490	24	18
RC-2785	50	510	58	14
RC-2815	20	345	18	13
RC-2855	51	335	10	73
RC-2870	32	855	8	15
RC-2875	61	45	20	44
RC-3889	121	1320	244	25
RC-3922	29	50	26	14
RC-3934	50	90	8	52
RC-3938	26	15	28	57
RC-3959	100	1550	56	27
RC-4200	51	965	12	17
RC-4225	60	65	10	53
RC-4245	54	805	6	12
RC-4315	51	950	10	12
RC-4410	88	1290	54	21

SAMPLE #	Ni	Ba	Fe%	Mn
RC-40	46	70	3.13	270
RC-150	1420	5	3.26	1300
RC-200	95	55	3.05	485
RC-360	32	225	2.69	530
RC-500	815	5	6.17	385
RC-650	85	25	3.35	515
RC-700	53	15	3.29	235
RC-870	305	5	5.39	445
RC-1145	1010	5	3.63	1240
RC-1375	66	75	6.08	385
RC-1520	118	5	4.94	670
RC-1675	32	45	2.71	365
RC-1845	42	80	3.84	445
RC-1875	103	25	3.40	255
RC-1925	76	140	3.32	119
RC-2150	125	110	5.44	205
RC-2390	745	5	2.24	1130
RC-2470	515	135	5.54	235
RC-2530	94	155	5.55	215
RC-2630	79	70	3.11	685
RC-2645	45	95	3.08	495
RC-2755	1360	5	3.46	1110
RC-2770	39	275	4.55	455
RC-2785	58	145	3.05	450
RC-2815	34	134	3.54	405
RC-2855	1410	5	4.29	590
RC-2870	70	90	3.02	67
RC-2875	895	5	2.63	935
RC-3889	49	205	5.70	330
RC-3922	54	135	3.08	455
RC-3934	1030	5	3.82	810
RC-3938	1320	5	3.10	1270
RC-3959	250	95	5.53	235
RC-4200	57	230	3.38	180
RC-4225	1000	5	3.14	970
RC-4245	34	220	3.21	470
RC-4315	81	220	2.98	410
RC-4410	176	80	4.89	245

SAMPLE #	Cr	Mg%	V	Al%
RC-40	35	5.07	73	8.19
RC-150	855	11.00	46	2.51
RC-200	55	6.56	72	7.51
RC-360	45	2.35	51	8.62
RC-500	600	16.00	150	5.51
RC-650	170	5.13	106	7.05
RC-700	85	6.48	119	7.66
RC-870	200	15.70	88	7.49
RC-1145	1380	11.20	54	2.61
RC-1375	74	8.89	149	13.60
RC-1520	98	6.58	147	8.04
RC-1675	30	3.22	46	8.02
RC-1845	45	5.06	94	9.41
RC-1875	40	4.19	64	7.31
RC-1925	120	5.09	82	8.99
RC-2150	70	12.60	100	12.20
RC-2390	595	11.70	12	1.08
RC-2470	360	16.90	99	12.00
RC-2530	190	8.09	165	12.40
RC-2630	115	6.74	74	5.55
RC-2645	90	4.43	92	6.07
RC-2755	1260	11.00	34	2.04
RC-2770	45	7.29	127	12.70
RC-2785	95	5.92	70	6.65
RC-2815	38	2.73	73	7.62
RC-2855	1700	10.80	85	5.42
RC-2870	65	3.54	77	7.05
RC-2875	825	8.65	38	1.54
RC-3889	110	6.66	159	12.90
RC-3922	100	3.38	80	6.50
RC-3934	1190	12.60	58	2.80
RC-3938	1210	12.80	31	1.42
RC-3959	115	10.90	154	10.00
RC-4200	45	4.25	83	8.21
RC-4225	1440	10.30	43	2.36
RC-4245	50	4.76	71	8.06
RC-4315	72	5.55	79	8.32
RC-4410	95	11.60	94	8.64

SAMPLE #	Be	Ca%	Cu	Ag
RC-40	0.25	0.86	72	0.4
RC-150	0.25	0.50	66	0.6
RC-200	0.25	1.90	35	0.6
RC-360	0.25	1.78	52	1.0
RC-500	0.25	2.15	31	3.8
RC-650	0.25	2.39	32	0.6
RC-700	0.25	0.15	101	0.4
RC-870	0.25	0.30	18	8.2
RC-1145	0.25	8.68	29	1.2
RC-1375	0.5	0.32	66	2.0
RC-1520	0.25	1.33	70	4.8
RC-1675	0.25	1.45	10	2.4
RC-1845	0.25	0.84	17	2.8
RC-1875	0.25	0.62	44	3.2
RC-1925	0.25	0.18	21	2.6
RC-2150	0.5	0.23	11	5.2
RC-2390	0.25	14.70	20	0.1
RC-2470	0.5	0.30	47	2.8
RC-2530	0.5	0.23	68	7.4
RC-2630	0.25	3.08	32	1.4
RC-2645	0.25	1.65	18	3.6
RC-2755	0.25	11.20	18	0.6
RC-2770	0.5	0.51	44	2.4
RC-2785	0.25	1.63	36	1.8
RC-2815	0.25	1.60	40	5.2
RC-2855	0.25	2.86	51	1.4
RC-2870	0.25	0.18	53	1.6
RC-2875	0.25	7.86	112	7.0
RC-3889	0.25	0.54	192	7.0
RC-3922	0.25	1.62	98	6.8
RC-3934	0.25	6.42	20	1.6
RC-3938	0.25	10.10	11	1.0
RC-3959	0.25	0.36	101	12.6
RC-4200	0.25	0.31	58	2.2
RC-4225	0.25	7.21	23	0.8
RC-4245	0.25	1.30	26	0.4
RC-4315	0.25	1.17	41	0.8
RC-4410	0.25	0.23	45	0.6

SAMPLE #	Ti%	Sr	Na%	K%
RC-40	0.322	14	0.42	2.88
RC-150	0.062	187	0.05	0.04
RC-200	0.254	42	0.49	2.46
RC-360	0.232	93	2.99	2.96
RC-500	0.254	57	0.51	0.04
RC-650	0.322	34	0.43	2.39
RC-700	0.322	9	0.46	2.38
RC-870	0.288	13	0.48	0.10
RC-1145	0.062	172	0.05	0.01
RC-1375	0.586	17	1.05	3.91
RC-1520	0.436	10	0.43	2.37
RC-1675	0.214	45	0.35	3.45
RC-1845	0.341	14	0.61	3.34
RC-1875	0.241	12	0.42	2.51
RC-1925	0.318	10	0.54	3.05
RC-2150	0.400	14	1.05	2.60
RC-2390	0.016	390	0.03	0.02
RC-2470	0.429	19	1.08	2.10
RC-2530	0.571	1240	1.02	3.75
RC-2630	0.243	60	0.41	1.83
RC-2645	0.238	37	0.42	2.46
RC-2755	0.019	136	0.09	0.02
RC-2770	0.515	16	0.88	4.25
RC-2785	0.261	26	0.38	2.37
RC-2815	0.267	46	0.45	3.34
RC-2855	0.175	51	0.33	0.02
RC-2870	0.292	9	0.32	2.80
RC-2875	0.032	171	0.01	0.03
RC-3889	0.543	14	0.88	4.23
RC-3922	0.268	25	0.28	2.76
RC-3934	0.082	110	0.15	0.01
RC-3938	0.030	170	0.07	0.01
RC-3959	0.348	16	0.78	2.28
RC-4200	0.336	7	0.43	3.03
RC-4225	0.025	120	0.12	0.02
RC-4245	0.325	13	0.46	3.01
RC-4315	0.346	18	0.47	3.04
RC-4410	0.366	8	0.49	0.95

SAMPLE #	As	Hg(ppb)	Sb	Bi
RC-40	4	50	3.0	0.1
RC-150	51	50	6.2	0.2
RC-200	3	20	2.4	0.1
RC-360	1	30	0.8	0.1
RC-500	63	20	1.4	0.1
RC-650	2	20	1.6	0.1
RC-700	1	20	1.0	0.1
RC-870	6	20	2.4	0.2
RC-1145	41	20	1.5	0.7
RC-1375	5	20	2.6	0.4
RC-1520	11	30	2.0	0.4
RC-1675	3	20	2.2	0.2
RC-1845	10	20	3.0	0.2
RC-1875	10	20	5.4	0.3
RC-1925	4	10	3.8	0.3
RC-2150	11	20	5.8	0.1
RC-2390	330	20	7.8	0.1
RC-2470	35	20	5.8	0.2
RC-2530	16	50	2.3	0.4
RC-2630	4	20	2.4	0.2
RC-2645	5	20	3.6	0.3
RC-2755	350	50	6.0	0.3
RC-2770	7	20	2.8	0.1
RC-2785	5	20	10.4	0.2
RC-2815	4	20	9.0	0.1
RC-2855	110	10	4.2	0.1
RC-2870	7	20	5.8	0.2
RC-2875	610	20	25.0	0.3
RC-3889	6	20	12.8	0.1
RC-3922	10	20	8.8	0.1
RC-3934	180	20	4.2	0.2
RC-3938	160	20	3.1	0.1
RC-3959	15	30	19.0	0.6
RC-4200	5	20	2.8	0.4
RC-4225	500	20	7.0	0.2
RC-4245	4	20	2.6	0.1
RC-4315	5	10	1.8	0.1
RC-4410	9	10	10.0	0.2

APPENDIX D-2: CORRELATION MATRIX USING 21 ELEMENT ICP ANALYSES PLUS Au, Ag, As, Sb, Bi, AND Hg from ROPES DEPOSIT

	Au	Mo	W	Zn	P	Pb	Co	Ni	Ba	Fe%	Mn	Cr	Mg%
Au	1												
Mo	195	1											
W	209	203	1										
Zn	226	087	236	1									
P	122	153	346	058	1								
Pb	334	44	38	066	334	1							
Co	-048	-164	-109	177	-536	-081	1						
Ni	-108	-203	-204	082	-462	-182	960	1					
Ba	077	09	093	-116	545	31	-575	-596	1				
Fe%	318	242	954	663	499	375	136	-063	063	1			
Mn	-201	-096	-259	-209	-493	-188	899	78	-509	-352	1		
Cr	-134	-233	-201	-001	-647	-164	930	945	-562	-095	74	1	
Mg%	081	041	128	62	-183	-038	69	631	-445	53	337	539	1
V	315	212	483	412	662	43	-241	-441	283	801	-588	-423	046
Al%	197	223	333	181	88	375	-582	-722	638	595	-794	-699	-204
Be	211	113	164	19	472	035	-057	-164	372	561	-268	-171	271
Ca%	-123	049	-265	-194	-672	-171	551	869	477	-392	806	892	326
Cu	413	331	42	-014	203	692	-064	-168	215	249	-206	-182	-166
Ag	633	326	417	318	218	412	-093	-199	103	511	-294	-226	112
Ti%	185	236	362	207	846	398	-563	-723	589	629	-76	-701	-2
Sr	3	014	173	-027	-126	14	177	156	-026	092	162	165	125
Na%	048	068	14	146	516	164	-376	-425	544	279	-408	-414	-172
K%	099	201	166	-223	712	31	-802	-858	734	123	-705	-806	-677
As	217	-064	-178	-087	-548	-12	557	63	-433	-277	601	649	314
Hg(ppb)	055	-084	098	-055	-129	043	185	189	-111	034	23	07	025
Sb	663	301	029	-079	-038	37	128	139	-042	021	07	084	097

	V	Al%	Be	Ca%	Cu	Ag	Ti%	Sr	Na%	K%	As	Hg(ppb)	Sb
V	1												
Al%	745	1											
Be	437	62	1										
Ca%	-626	-775	-252	1									
Cu	458	295	-01	-264	1								
Ag	503	329	154	-27	447	1							
Ti%	843	956	581	-759	361	323	1						
Sr	093	-035	326	22	02	16	03	1					
Na%	331	607	385	-415	146	13	489	041	1				
K%	5	875	36	-666	285	168	796	-049	482	1			
As	-493	-646	-148	749	-02	-051	-648	184	-373	-618	1		
Hg(ppb)	019	-066	118	064	15	079	-046	478	07	-03	874	1	
Sb	-053	-134	-116	162	504	637	-16	-028	-18	-157	493	-021	1

APPENDIX E: MINERAL COMPOSITIONS AND MINERAL STRUCTURAL FORMULAE

Explanation for data tables in Appendix E-1 through E-6:

<u>**Order of columns in data tables:**</u>

Sample #: Sample # on traverse location sketch, following page

Grain #: Sequential analyses on different mineral grains in same sample

Rock Type:
AS = quartz - sericite - chlorite rock from south of layer of microcrystalline carbonate - quartz rock
AN = quartz - sericite - chlorite rock from north of layer of microcrystalline carbonate - quartz rock
B = carbonate - quartz - chlorite rock
T = carbonate - talc rock
P = serpentinitic peridotite

Traverse #: refers to traverse location sketch on the following page, samples labeled 0 are not on any of the 4 traverses

Distance: distance in feet north from first sample in a traverse

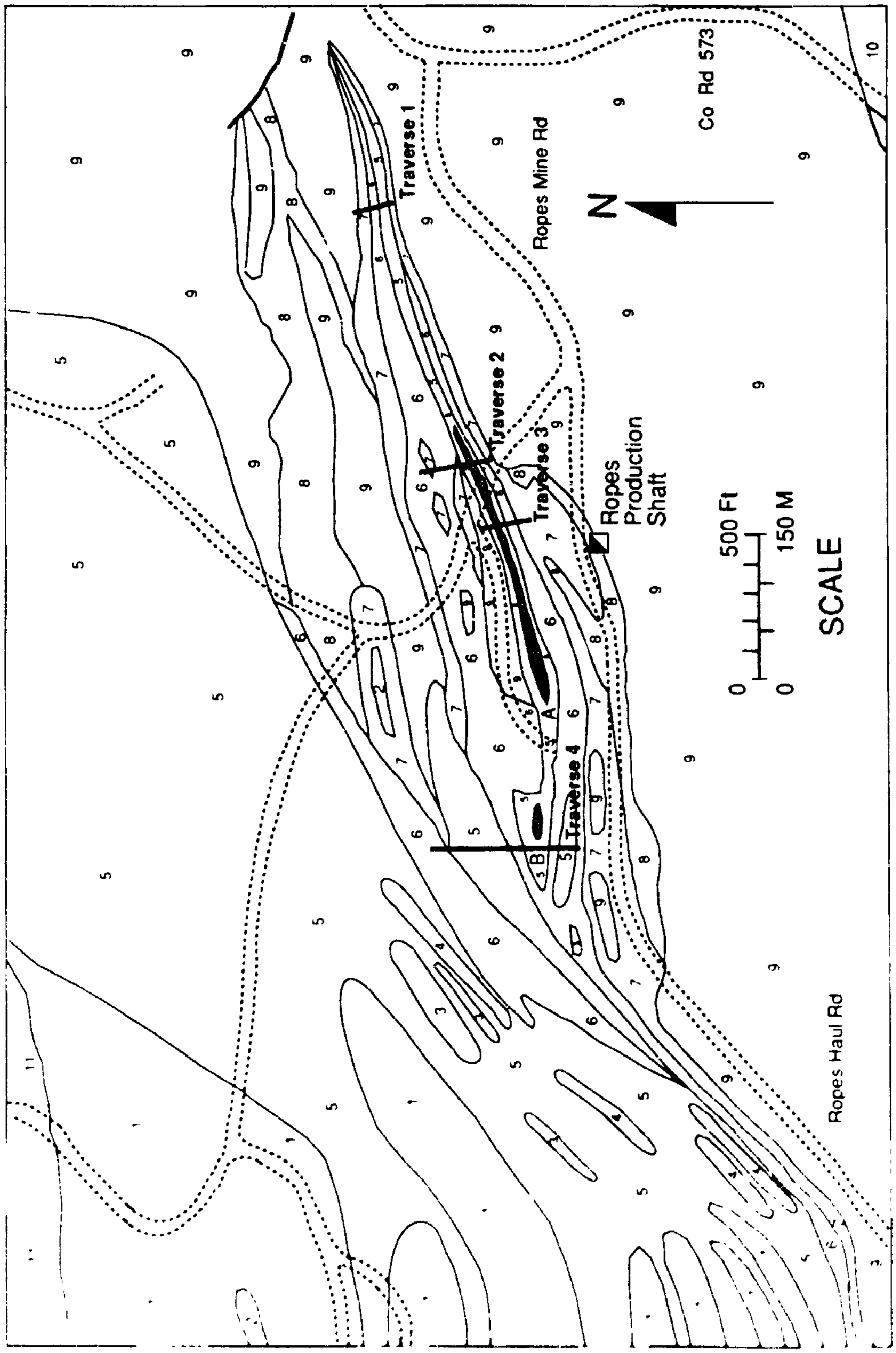
Mode: type of site which the analyzed grain is in:
F = on foliation
V = in quartz or carbonate veinlet
M = grain of a type which is evenly dispersed within the mass of the rock (not in veinlet or on foliation)
C = grain within a cluster or domain of the same mineral

Analyses in columns through SUM are in wt% oxide

Values in columns after SUM are in # of cations on the basis of 22 oxygens in mineral structural formula, except for carbonate minerals where these values are # of cations on the basis of 2 oxygens

F/M = Fe/Mg cation ratio

F/FM = Fe/(Fe+Mg) cation ratio



Traverse 1
Traverse 2
Traverse 3
Traverse 4
Ropes Mine Rd
Co Rd 573
N
Ropes Production Shaft
0 500 Ft
0 150 M
SCALE
A
B
Ropes Haul Rd

APPENDIX E-1: CHLORITE

	A	B	C	D
1	SAMPLE #	GRAIN #	ROCK TYPE	TRAVERSE
2				
3	RISO-50	1	T	3
4	RISO-50	2	T	3
5	RISO-50	3	T	3
6	RISO-50	4	T	3
7	RISO-50	5	T	3
8	RISO-50	6	T	3
9	RISO-49	1	B	3
10	RISO-49	2	B	3
11	RS-26-113	1	B	1
12	RS-26-113	2	B	1
13	RS-26-113	3	B	1
14	RS-26-113	4	B	1
15	RS-26-113	5	B	1
16	RS-26-191	1	T	1
17	RS-26-191	2	T	1
18	RS-25-191	3	T	1
19	RS-26-166	1	B	1
20	RS-26-166	2	B	1
21	RS-26-166	3	B	1
22	RS-25-152	1	A	4
23	RS-25-152	2	A	4
24	RS-25-152	3	A	4
25	RS-25-80	1	B	4
26	RISO-16	1	AS	0
27	RISO-16	2	AS	0
28	RISO-16	3	AS	0
29	RISO-18	1	A	0
30	RISO-18	2	A	0
31	RISO-18	3	A	0
32	RISO-18	4	A	0
33	RS-16-482	1	P	2
34	RS-16-482	2	P	2
35	RS-16-482	3	P	2
36	RS-24-193	1	A	4
37	RS-24-193	2	A	4
38	RS-24-193	3	A	4
39	RS-25-256	1	B	4
40	RS-25-256	2	B	4
41	RS-25-256	3	B	4
42	RS-16-563	1	T	2
43	RS-16-563	2	T	2
44	RS-16-563	3	T	2
45	RISO-48	1	AS	3
46	RISO-48	2	AS	3
47	RS-27-174	1	A	4
48	RS-27-174	2	A	4

	E	F	G	H	I
1	DISTANCE	MODE	SIO2	TiO2	Al2O3
2					
3	230	F	28.73	0.17	15.17
4	230	V	31.23	0.10	16.83
5	230	F	27.44	0.05	16.74
6	230	F	28.38	0.07	16.74
7	230	F	28.30	0.02	16.72
8	230	V	30.46	0.03	17.49
9	72	V	28.56	0.03	16.40
10	72	M	28.79	0.03	18.15
11	0	M	28.26	0.03	19.78
12	0	M	29.73	0.03	19.83
13	0	M	28.88	0.08	20.44
14	0	M	29.00	0.03	20.14
15	0	V	29.69	0.03	20.27
16	55	F	32.60	0.00	15.04
17	55	M	31.68	0.00	14.02
18	55	M	31.51	0.00	13.70
19	37	V	28.64	0.02	20.72
20	37	M	27.78	0.08	20.78
21	37	V	28.15	0.05	20.12
22	160	M	28.06	0.00	21.50
23	160	M	27.91	0.00	0.28
24	160	F	28.21	0.00	21.52
25	100	V	28.11	0.00	22.35
26	0	M	28.26	0.13	23.27
27	0	M	29.05	0.05	25.24
28	0	M	35.27	0.27	22.44
29	0	M	28.68	0.17	22.35
30	0	M	28.71	0.12	20.42
31	0	M	27.12	0.07	21.33
32	0	F	28.71	0.07	25.44
33	212	F	42.33	0.00	7.90
34	212	V	31.70	0.00	16.19
35	212	M	29.82	0.00	16.64
36	370	F	28.58	0.00	18.38
37	370	F	32.04	0.00	16.38
38	370	F	31.27	0.00	15.81
39	230	F	27.57	0.00	20.93
40	230	F	27.94	0.00	21.36
41	230	F	27.42	0.00	21.42
42	173	F	34.05	0.00	14.19
43	173	F	32.45	0.00	14.38
44	173	F	33.33	0.00	15.87
45	98	M	28.83	0.00	21.52
46	98	F	28.73	0.00	21.82
47	502	M	28.98	0.08	21.80
48	502	F	27.61	0.03	20.55

	J	K	L	M	N
1	Cr2O3	FeO	MnO	MgO	CaO
2					
3	0.31	14.66	0.02	23.39	0.13
4	0.86	14.38	0.14	23.97	0.10
5	1.30	14.69	0.10	22.95	0.06
6	1.21	14.90	0.05	23.18	0.10
7	1.26	14.52	0.12	24.07	0.10
8	1.29	11.37	0.01	26.76	0.04
9	1.58	11.55	0.06	26.20	0.04
10	1.59	11.84	0.13	26.51	0.07
11	1.21	11.93	0.12	25.82	0.00
12	0.76	12.29	0.05	26.00	0.00
13	0.80	11.83	0.09	26.28	0.00
14	1.07	12.17	0.13	26.84	0.00
15	0.83	12.56	0.00	26.73	0.00
16	1.45	9.58	0.05	29.50	0.00
17	1.39	9.13	0.09	29.71	0.00
18	0.82	9.31	0.00	30.28	0.00
19	0.03	11.99	0.05	26.15	0.00
20	0.10	11.92	0.06	25.82	0.00
21	0.19	12.23	0.05	25.73	0.00
22	0.04	10.65	0.04	26.00	0.00
23	0.00	10.83	0.09	25.83	0.00
24	0.00	10.57	0.00	26.03	0.00
25	0.06	15.17	0.17	22.73	0.00
26	0.02	8.85	0.06	26.79	0.00
27	0.07	8.24	0.06	25.72	0.00
28	0.06	8.63	0.14	23.92	0.00
29	0.13	16.51	0.14	23.26	0.00
30	0.03	15.19	0.19	23.23	0.00
31	0.09	15.69	0.15	22.80	0.00
32	0.03	11.69	0.08	24.22	0.00
33	1.18	5.09	0.00	28.85	0.00
34	1.23	8.08	0.00	28.90	0.00
35	1.56	8.04	0.00	28.75	0.00
36	1.56	10.44	0.05	26.20	0.00
37	0.44	9.18	0.03	28.04	0.00
38	0.79	8.92	0.01	27.75	0.00
39	1.46	11.12	0.04	24.17	0.00
40	1.83	10.92	0.00	24.26	0.00
41	1.62	11.50	0.05	24.37	0.00
42	1.86	9.92	0.04	27.57	0.00
43	0.92	10.10	0.03	29.18	0.00
44	0.94	10.26	0.03	28.09	0.00
45	0.09	9.07	0.03	26.61	0.00
46	0.10	8.85	0.05	26.49	0.00
47	0.03	13.85	0.21	21.32	0.01
48	0.04	13.67	0.15	22.76	0.00

	O	P	Q	R	S
1	Na2O	K2O	SUM	Si	Al(T)
2					
3	0.00	0.07	82.65	6.084	1.916
4	0.05	0.11	87.77	6.180	1.820
5	0.00	0.06	83.39	0.006	2.213
6	0.00	0.07	84.70	5.882	2.118
7	0.00	0.11	85.22	5.827	2.173
8	0.00	0.01	87.46	5.969	2.031
9	0.00	0.02	84.44	5.843	2.157
10	0.00	0.01	87.12	5.709	2.291
11	0.05	0.00	87.20	5.589	2.411
12	0.09	0.01	88.79	5.755	2.245
13	0.01	0.10	88.51	5.608	2.392
14	0.05	0.00	89.43	5.590	2.410
15	0.07	0.00	90.18	5.668	2.332
16	0.11	0.00	88.33	6.267	1.733
17	0.07	0.01	86.10	6.253	1.747
18	0.18	0.02	85.82	6.243	1.757
19	0.08	0.00	87.68	5.604	2.396
20	0.07	0.07	86.68	5.510	2.490
21	0.03	0.00	86.55	5.597	2.403
22	0.03	0.00	86.32	5.540	2.463
23	0.03	0.00	86.45	5.505	2.495
24	0.00	0.00	86.33	5.558	2.442
25	0.00	0.02	88.61	5.522	2.478
26	0.01	0.55	87.94	5.434	2.566
27	0.04	1.99	90.46	5.442	2.558
28	0.01	0.05	90.79	6.424	1.576
29	0.05	0.00	3.14	5.503	2.497
30	0.03	0.00	87.92	5.691	2.309
31	0.00	0.04	87.29	5.446	2.554
32	0.03	0.08	90.45	5.408	2.592
33	0.00	0.00	85.35	8.047	0.000
34	0.01	0.00	86.11	6.193	1.807
35	0.23	0.00	85.04	5.934	2.066
36	0.00	0.00	85.21	5.743	2.257
37	0.03	0.00	86.14	6.270	1.730
38	0.00	0.00	84.55	6.242	1.758
39	0.00	0.00	85.29	5.544	2.456
40	0.00	0.00	86.31	5.544	2.456
41	0.00	0.00	86.38	5.460	2.540
42	0.00	0.00	87.63	6.583	1.417
43	0.00	0.00	87.06	6.337	1.663
44	0.00	0.00	88.52	6.379	1.621
45	0.00	0.00	86.15	5.641	2.359
46	0.01	0.00	86.05	5.622	2.378
47	0.03	0.83	87.14	5.764	2.236
48	0.00	0.00	84.81	5.637	2.363

	T	U	V	W	X
1	Al(O)	Ti	Cr	Mn	Fe
2					
3	1.869	0.027	0.052	0.004	2.596
4	2.105	0.015	0.135	0.023	2.380
5	1.946	0.008	0.217	0.018	2.59[illegible]
6	1.970	0.011	0.198	0.009	2.582
7	1.884	0.003	0.205	0.021	2.500
8	2.009	0.004	0.200	0.002	1.863
9	1.797	0.005	0.256	0.010	1.976
10	1.949	0.004	0.249	0.022	1.963
11	2.198	0.004	0.189	0.020	1.973
12	2.279	0.004	0.116	0.008	1.990
13	2.286	0.012	0.123	0.015	1.921
14	2.164	0.004	0.163	0.021	1.962
15	2.228	0.004	0.125	0.000	2.005
16	1.675	0.000	0.220	0.008	1.540
17	1.513	0.000	0.217	0.015	1.507
18	1.442	0.000	0.128	0.000	1.543
19	2.381	0.003	0.005	0.008	1.962
20	2.368	0.012	0.016	0.010	1.977
21	2.311	0.007	0.300	0.008	2.034
22	2.536	0.000	0.006	0.007	1.757
23	2.563	0.000	0.000	0.015	1.786
24	2.555	0.000	0.000	0.000	1.742
25	2.696	0.000	0.009	0.028	2.492
26	2.706	0.019	0.003	0.010	1.423
27	3.013	0.007	0.010	0.010	1.291
28	3.241	0.037	0.009	0.022	1.315
29	2.556	0.025	0.020	0.023	2.649
30	2.460	0.018	0.005	0.032	2.518
31	2.494	0.011	0.014	0.026	2.635
32	3.054	0.010	0.004	0.029	1.841
33	1.770	0.000	0.177	0.000	0.809
34	1.920	0.000	0.190	0.000	1.320
35	1.836	0.000	0.245	0.000	1.338
36	2.096	0.000	0.248	0.009	1.755
37	2.047	0.000	0.068	0.005	1.502
38	1.961	0.000	0.125	0.002	1.489
39	2.504	0.000	0.232	0.007	1.870
40	2.538	0.000	0.287	0.000	1.812
41	2.486	0.000	0.255	0.008	1.915
42	1.816	0.000	0.284	0.007	1.604
43	0.002	0.000	0.142	0.005	1.649
44	1.957	0.000	0.142	0.005	1.642
45	2.604	0.000	0.014	0.005	1.484
46	0.003	0.000	0.015	0.008	1.448
47	2.874	0.012	0.005	0.035	2.304
48	2.582	0.005	0.006	0.026	2.334

	Y	Z	AA	AB	AC
1	Mg	Na	Ca	K	O
2					
3	7.382	0.000	0.029	0.019	28.000
4	7.070	0.019	0.021	0.028	28.000
5	7.214	0.000	0.014	0.016	28.000
6	7.160	0.000	0.022	0.019	28.000
7	7.387	0.000	0.022	0.029	28.000
8	7.817	0.000	0.008	0.002	28.000
9	7.990	0.000	0.009	0.005	28.000
10	7.835	0.000	0.015	0.003	28.000
11	7.611	0.019	0.000	0.000	28.000
12	7.502	0.034	0.000	0.002	28.000
13	7.607	0.004	0.000	0.025	28.000
14	7.711	0.019	0.000	0.000	28.000
15	7.606	0.026	0.000	0.000	28.000
16	8.453	0.041	0.000	0.000	28.000
17	8.740	0.027	0.000	0.003	28.000
18	8.942	0.069	0.000	0.005	28.000
19	7.626	0.030	0.000	0.000	28.000
20	7.634	0.027	0.000	0.018	28.000
21	7.625	0.012	0.000	0.000	28.000
22	7.647	0.011	0.000	0.000	28.000
23	7.594	0.011	0.000	0.000	28.000
24	7.644	0.000	0.000	0.000	28.000
25	6.655	0.000	0.000	0.005	28.000
26	7.678	0.004	0.000	0.135	28.000
27	7.181	0.015	0.000	0.475	28.000
28	6.494	0.004	0.000	0.012	28.000
29	6.652	0.019	0.000	0.000	28.000
30	6.863	0.012	0.000	0.000	28.000
31	6.825	0.000	0.000	0.010	28.000
32	6.800	0.011	0.000	0.019	28.000
33	8.175	0.000	0.000	0.000	28.000
34	8.415	0.004	0.000	0.000	28.000
35	8.527	0.089	0.000	0.000	28.000
36	7.848	0.000	0.000	0.000	28.000
37	8.178	0.011	0.000	0.000	28.000
38	8.257	0.000	0.000	0.000	28.000
39	7.245	0.000	0.000	0.000	28.000
40	7.175	0.000	0.000	0.000	28.000
41	7.233	0.000	0.000	0.000	28.000
42	7.945	0.000	0.000	0.000	28.000
43	8.493	0.000	0.000	0.000	28.000
44	8.013	0.000	0.000	0.000	28.000
45	7.761	0.000	0.000	0.000	28.000
46	7.726	0.004	0.000	0.000	28.000
47	6.321	0.012	0.002	0.211	28.000
48	6.927	0.000	0.000	0.000	28.000

	AD	AE
1	F/M	F/FM
2		
3	0.352	0.260
4	0.340	0.254
5	0.362	0.266
6	0.362	0.266
7	0.341	0.254
8	0.239	0.193
9	0.025	0.199
10	0.253	0.202
11	0.262	0.208
12	0.266	0.210
13	0.255	0.203
14	0.257	0.205
15	0.264	0.209
16	0.183	0.155
17	0.174	0.148
18	0.173	0.147
19	0.258	0.205
20	0.260	0.207
21	0.268	0.211
22	0.231	0.187
23	0.237	0.192
24	0.228	0.186
25	0.379	0.275
26	0.187	0.157
27	0.181	0.153
28	0.206	0.171
29	0.402	0.287
30	0.372	0.271
31	0.390	0.280
32	0.275	0.216
33	0.099	0.090
34	0.157	0.136
35	0.570	0.136
36	0.225	0.183
37	0.184	0.156
38	0.181	0.153
39	0.259	0.206
40	0.253	0.202
41	0.266	0.210
42	0.203	0.169
43	0.195	0.163
44	0.206	0.170
45	0.192	0.161
46	0.189	0.159
47	0.370	0.270
48	0.341	0.254

	A	B	C	D
49	SAMPLE #	GRAIN #	ROCK TYPE	TRAVERSE
50				
51	RS-27-174	3	A	4
52	RS-27-174	4	A	4
53	RS-27-174	5	A	4
54	RS-27-215	1	B	4
55	RS-27-215	2	B	4
56	RISO-27	1	A	0
57	RISO-30	1	A	0
58	RS-27-277	1	B	4
59	RS-27-277	2	B	4
60	RS-27-277	3	B	4
61	RS-27-73	1	A	4
62	RS-27-73	2	A	4
63	RS-27-73	3	A	4
64	RS-25-335	1	B	4
65	RS-25-335	2	B	4
66	RS-25-335	3	B	4
67	I152-450E-S	1	A	0
68	I152-450E-S	2	A	0
69	I152-450E-S	3	A	0
70	I152-450E-S	4	A	0
71	I152-450E-S	5	A	0
72	I152-550E-N	1	A	0
73	RISO-42	1	AS	3
74	RISO-42	2	AS	3
75	RISO-45	1	T	3
76	RISO-47	1	AS	3
77	RISO-47	2	AS	3
78	RS-16-655	1	B	2
79	RS-16-655	2	B	2
80	RS-16-790	1	B	2
81	RS-16-790	2	B	2
82	RS-16-790	3	B	2
83	RS-26-145	1	A	1
84	RS-26-145	2	A	1
85	RS-25-135	1	A	4
86	RS-25-135	2	A	4
87	RS-25-171	1	A	4
88	RS-25-171	2	A	4
89	RS-25-216	1	A	4
90	RS-25-216	2	A	4
91	I152-650E-N	1	A	0

	E	F	G	H	I
49	DISTANCE	MODE	SiO2	TiO2	Al2O3
50					
51	502	F	29.11	0.00	21.08
52	502	F	28.81	0.03	21.08
53	502	M	28.60	0.02	21.82
54	530	V	29.30	0.02	20.14
55	530	F	30.12	0.00	19.32
56	0	F	28.51	0.05	21.78
57	0	M	29.60	0.08	22.12
58	570	V	30.46	0.00	17.47
59	570	F	32.47	0.00	17.07
60	570	V	30.76	0.00	16.19
61	430	F	28.88	0.05	21.86
62	430	M	28.62	0.05	21.35
63	430	M	29.35	0.07	19.87
64	288	F	29.99	0.00	18.72
65	288	F	29.77	0.08	19.08
66	288	F	30.22	0.03	19.23
67	0	F	29.50	0.03	21.09
68	0	M	28.30	0.08	20.80
69	0	M	28.63	0.04	20.54
70	0	M	28.65	0.01	21.02
71	0	M	29.88	0.04	21.42
72	0	M	28.02	0.11	21.74
73	150	F	28.30	0.05	22.11
74	150	F	29.14	0.04	21.80
75	230	F	33.49	0.01	14.65
76	120	M	27.14	0.01	22.18
77	120	M	26.51	0.01	21.80
78	126	F	36.58	0.00	18.23
79	126	F	28.45	0.00	21.50
80	57	F	28.11	0.02	19.31
81	57	F	29.01	0.00	19.39
82	57	F	28.61	0.02	19.10
83	22	M	28.43	0.00	21.82
84	22	M	27.73	0.00	22.11
85	0	F	28.47	0.04	19.01
86	0	F	28.33	0.00	19.14
87	172	F	28.46	0.03	23.04
88	172	F	27.59	0.04	22.36
89	201	M	27.25	0.00	22.47
90	201	M	27.46	0.00	22.36
91	0	M	36.11	0.05	21.63

	J	K	L	M	N
49	Cr2O3	FeO	MnO	MgO	CaO
50					
51	0.00	14.24	0.10	23.18	0.00
52	0.00	14.21	0.17	22.75	0.00
53	0.03	14.47	0.14	23.18	0.00
54	1.24	11.03	0.04	24.59	0.06
55	0.94	11.05	0.01	24.69	0.06
56	0.10	10.51	0.01	24.72	0.00
57	0.00	10.89	0.06	23.29	0.03
58	1.39	6.88	0.03	29.25	0.00
59	1.39	6.82	0.00	29.53	0.01
60	1.43	6.16	0.00	28.63	0.11
61	0.06	17.21	0.14	19.95	0.01
62	0.01	17.40	0.08	19.98	0.03
63	0.28	17.00	0.12	20.81	0.01
64	1.55	10.94	0.00	25.27	0.07
65	1.64	11.05	0.00	25.17	0.01
66	1.23	11.38	0.01	25.37	0.01
67	0.00	6.68	0.07	28.65	0.07
68	0.00	6.50	0.00	27.87	0.04
69	0.04	6.70	0.02	28.81	0.16
70	0.00	6.29	0.04	28.37	0.04
71	0.00	6.78	0.04	28.79	0.03
72	0.00	0.02	0.06	25.85	0.04
73	0.08	13.52	0.02	23.11	0.00
74	0.02	13.56	0.04	24.00	0.00
75	2.00	10.32	0.01	26.38	0.00
76	0.05	21.48	0.05	18.12	0.00
77	0.02	21.81	0.09	18.29	0.00
78	0.00	10.64	0.05	22.08	0.00
79	0.00	11.72	0.09	24.92	0.00
80	1.26	11.77	0.07	24.29	0.00
81	0.64	12.04	0.00	25.21	0.00
82	0.84	12.14	0.01	24.71	0.11
83	0.00	13.19	0.00	23.67	0.00
84	0.02	13.04	0.04	23.34	0.00
85	1.27	13.04	0.07	24.92	0.16
86	1.27	12.39	0.12	24.80	0.11
87	0.00	10.58	0.07	25.42	0.00
88	0.01	10.70	0.14	23.88	0.04
89	0.00	10.50	0.05	24.88	0.16
90	0.00	10.31	0.08	24.68	0.04
91	0.00	6.40	0.08	19.69	0.05

	O	P	Q	R	S
49	Na2O	K2O	SUM	Si	Al(T)
50					
51	0.00	0.00	87.71	5.739	2.261
52	0.08	0.00	87.23	5.716	2.284
53	0.00	0.00	88.26	5.615	2.385
54	0.00	0.00	86.42	5.790	2.210
55	0.00	0.00	86.19	5.955	2.045
56	0.00	0.24	85.92	5.641	2.359
57	0.00	0.10	86.17	5.820	2.180
58	0.00	0.00	85.48	5.971	2.029
59	0.01	0.00	87.30	6.205	1.795
60	0.00	0.00	83.28	6.161	1.839
61	0.01	0.11	88.28	5.739	2.261
62	0.00	0.22	87.74	5.738	2.262
63	0.04	0.13	87.68	5.881	2.119
64	0.00	0.00	86.54	5.922	2.078
65	0.00	0.00	86.80	5.866	2.134
66	0.00	0.00	87.48	5.905	2.095
67	0.04	0.00	86.13	5.704	2.296
68	0.04	0.00	83.63	5.638	2.362
69	0.01	0.00	84.95	5.628	2.372
70	0.09	0.00	84.51	5.642	2.358
71	0.00	0.00	86.98	5.717	2.283
72	0.01	0.00	86.81	5.507	2.493
73	0.05	0.04	87.28	5.592	2.408
74	0.03	0.01	88.64	5.662	2.338
75	0.02	0.00	86.88	6.546	1.454
76	0.09	0.09	89.21	5.478	2.522
77	0.00	0.01	88.54	5.411	2.589
78	0.00	0.00	87.58	6.956	1.044
79	0.00	0.00	86.68	5.612	2.388
80	0.00	0.00	84.83	5.704	2.296
81	0.00	0.00	86.29	5.773	2.227
82	0.00	0.00	85.54	5.758	2.242
83	0.02	0.00	87.13	5.615	2.385
84	0.05	0.00	86.33	5.532	2.468
85	0.00	0.01	86.99	5.678	2.322
86	0.00	0.00	86.16	5.684	2.316
87	0.05	0.01	87.66	5.513	2.487
88	0.00	0.03	84.79	5.537	2.463
89	0.02	0.02	85.35	5.437	2.563
90	0.02	0.00	84.95	5.492	2.508
91	0.05	1.27	85.33	6.915	1.085

	T	U	V	W	X
49	Al(O)	Ti	Cr	Mn	Fe
50					
51	2.635	0.000	0.000	0.017	2.348
52	2.668	0.004	0.000	0.029	2.358
53	2.663	0.003	0.005	0.023	2.376
54	2.480	0.003	0.194	0.007	1.823
55	2.455	0.000	0.147	0.002	1.827
56	2.719	0.007	0.016	0.002	1.739
57	2.945	0.012	0.000	0.010	1.791
58	2.007	0.000	0.215	0.005	1.128
59	2.050	0.000	0.210	0.000	1.090
60	1.983	0.000	0.226	0.000	1.032
61	2.858	0.007	0.009	0.024	2.860
62	2.783	0.008	0.002	0.014	2.918
63	2.573	0.011	0.044	0.020	2.849
64	2.277	0.000	0.242	0.000	1.806
65	2.295	0.012	0.255	0.000	1.821
66	2.333	0.004	0.190	0.002	1.860
67	2.510	0.004	0.000	0.011	1.080
68	2.520	0.012	0.000	0.000	1.083
69	2.387	0.006	0.006	0.003	1.102
70	2.519	0.001	0.000	0.007	1.036
71	2.546	0.006	0.000	0.006	1.085
72	2.542	0.016	0.000	0.010	1.805
73	2.740	0.007	0.012	0.003	2.234
74	2.654	0.006	0.003	0.007	2.204
75	1.920	0.001	0.309	0.002	1.687
76	2.753	0.002	0.008	0.009	3.626
77	2.654	0.002	0.000	0.016	3.723
78	3.041	0.000	0.000	0.008	1.692
79	2.610	0.000	0.000	0.015	1.934
80	2.321	0.003	0.202	0.012	1.997
81	2.319	0.000	0.101	0.000	2.004
82	2.287	0.003	0.134	0.002	2.043
83	2.693	0.000	0.000	0.000	2.179
84	2.730	0.000	0.003	0.007	2.176
85	2.145	0.006	0.200	0.012	2.175
86	2.209	0.000	0.201	0.020	2.079
87	2.771	0.004	0.000	0.011	1.714
88	2.825	0.006	0.002	0.024	1.796
89	2.719	0.000	0.000	0.008	1.752
90	2.762	0.000	0.000	0.014	1.724
91	3.795	0.007	0.000	0.013	1.025

	Y	Z	AA	AB	AC
49	Mg	Na	Ca	K	O
50					
51	6.811	0.000	0.000	0.000	28.000
52	6.728	0.031	0.000	0.000	28.000
53	6.783	0.000	0.000	0.000	28.000
54	7.243	0.000	0.000	0.000	28.000
55	7.275	0.000	0.000	0.000	28.000
56	7.290	0.000	0.000	0.061	28.000
57	6.826	0.000	0.000	0.025	28.000
58	8.546	0.000	0.000	0.000	28.000
59	8.412	0.004	0.004	0.000	28.000
60	8.548	0.000	0.000	0.000	28.000
61	5.909	0.004	0.002	0.028	28.000
62	5.971	0.000	0.006	0.056	28.000
63	6.215	0.016	0.002	0.033	28.000
64	7.437	0.000	0.015	0.000	28.000
65	7.392	0.000	0.002	0.000	28.000
66	7.389	0.000	0.002	0.000	28.000
67	8.258	0.015	0.015	0.000	28.000
68	8.275	0.015	0.009	0.000	28.000
69	8.442	0.004	0.034	0.000	28.000
70	8.327	0.034	0.008	0.000	28.000
71	8.210	0.000	0.006	0.000	28.000
72	7.573	0.004	0.008	0.000	28.000
73	6.806	0.019	0.000	0.010	28.000
74	6.951	0.011	0.000	0.002	28.000
75	7.686	0.008	0.000	0.000	28.000
76	5.451	0.035	0.000	0.023	28.000
77	5.564	0.000	0.000	0.003	28.000
78	6.258	0.000	0.000	0.000	28.000
79	7.327	0.000	0.000	0.000	28.000
80	7.346	0.000	0.000	0.000	28.000
81	7.477	0.000	0.000	0.000	28.000
82	7.412	0.000	0.024	0.000	28.000
83	6.968	0.008	0.000	0.000	28.000
84	6.940	0.019	0.000	0.000	28.000
85	7.407	0.000	0.034	0.003	28.000
86	7.417	0.000	0.024	0.000	28.000
87	7.339	0.019	0.000	0.002	28.000
88	7.144	0.000	0.009	0.008	28.000
89	7.399	0.008	0.034	0.005	28.000
90	7.357	0.008	0.009	0.000	28.000
91	5.620	0.019	0.010	0.310	28.000

	AD	AE
49	F/M	F/FM
50		
51	0.347	0.258
52	0.355	0.262
53	0.354	0.261
54	0.253	0.202
55	0.251	0.201
56	0.239	0.193
57	0.264	0.209
58	0.133	0.117
59	0.130	0.115
60	0.121	0.108
61	0.388	0.328
62	0.491	0.329
63	0.462	0.316
64	0.243	0.195
65	0.246	0.198
66	0.252	0.201
67	0.132	0.117
68	0.131	0.116
69	0.131	0.116
70	0.125	0.111
71	0.133	0.117
72	0.240	0.193
73	0.329	0.247
74	0.318	0.241
75	0.220	0.180
76	0.667	0.400
77	0.672	0.402
78	0.272	0.214
79	0.266	0.210
80	0.274	0.215
81	0.268	0.211
82	0.276	0.216
83	0.313	0.238
84	0.314	0.239
85	0.295	0.228
86	0.283	0.221
87	0.235	0.190
88	0.255	0.203
89	0.238	0.192
90	0.236	0.191
91	0.185	0.156

APPENDIX E-2: SERICITE

	A	B	C	D
1	SAMPLE #	GRAIN #	ROCK TYPE	TRAVERSE
2				
3	RISO-42	1	AS	3
4	RISO-42	2	AS	3
5	RISO-42	3	AS	3
6	RISO-47	1	AS	3
7	RISO-43	1	AS	3
8	RISO-43	2	AS	3
9	RISO-43	3	AS	3
10	RISO-43	4	AS	3
11	RISO-43	5	AS	3
12	RISO-43	6	AS	3
13	RS-25-145	1	AS	1
14	RS-25-145	2	AS	1
15	RS-26-126	1	AS	1
16	RS-16-655	1	B	2
17	RS-16-655	2	B	2
18	RS-16-655	3	B	2
19	RS-16-655	4	B	2
20	RS-16-655	5	B	2
21	RS-25-80	1	B	4
22	RS-25-80	2	B	4
23	RS-25-80	3	B	4
24	RS-25-80	4	B	4
25	RISO-16	1	AS	0
26	RISO-16	2	AS	0
27	RISO-16	3	AS	0
28	RISO-22	1	AN	0
29	RISO-22	2	AN	0
30	RISO-22	3	AN	0
31	RISO-22	4	AN	0
32	RISO-22	5	AN	0
33	RS-16-71	1	A	2
34	RS-16-71	2	A	2
35	RS-16-71	3	A	2
36	RISO-44	1	AS	3
37	RISO-44	2	AS	3
38	RISO-44	3	AS	3
39	RISO-32	1	AS	0
40	RISO-32	2	AS	0
41	RISO-32	3	AS	0
42	RS-27-174	1	A	4
43	RS-27-174	2	A	4
44	RS-27-174	3	A	4
45	RISO-27	1	A	0
46	RISO-27	2	A	0
47	RISO-27	3	A	0
48	RISO-27	4	A	0

	E	F	G	H	I
1	DISTANCE	MODE	SiO2	TiO2	Al2O3
2					
3	150	M	48.08	0.29	29.81
4	150	M	47.83	0.19	29.41
5	150	V	46.91	0.26	30.92
6	120	M	46.89	0.79	27.47
7	180	M	43.72	0.31	32.85
8	180	M	41.82	0.31	32.66
9	180	M	45.00	0.30	33.51
10	180	M	44.17	0.25	32.51
11	180	M	42.97	0.21	33.21
12	180	M	39.10	0.19	32.79
13	23	M	49.09	1.47	28.85
14	23	M	43.98	1.67	29.83
15	9	M	54.33	0.26	25.54
16	126	M	49.45	0.26	33.89
17	126	M	49.45	0.26	33.89
18	126	M	47.63	0.35	34.13
19	126	M	47.87	0.37	32.68
20	126	M	48.88	0.29	30.98
21	100	M	47.99	0.23	29.62
22	100	M	47.01	0.23	29.43
23	100	M	48.00	0.28	29.26
24	100	M	48.47	0.15	29.64
25	0	M	48.58	0.21	30.00
26	0	M	45.97	0.18	29.81
27	0	M	47.96	0.22	31.77
28	0	M	47.89	0.22	32.70
29	0	M	48.38	0.30	33.28
30	0	M	48.23	0.50	33.21
31	0	M	49.39	0.41	32.06
32	0	V	46.67	0.27	32.11
33	96	F	49.92	0.17	33.00
34	96	M	48.51	0.23	32.23
35	96	M	48.73	2.50	32.91
36	205	M	45.77	0.24	33.13
37	205	M	42.74	0.10	27.30
38	205	M	49.13	0.26	30.51
39	0	M	44.88	0.26	31.28
40	0	M	43.27	0.27	31.64
41	0	M	48.38	0.06	31.60
42	502	M	49.56	0.17	30.22
43	502	F	49.28	0.07	30.21
44	502	M	50.22	0.05	31.89
45	0	F	51.64	0.57	29.49
46	0	F	48.26	0.62	27.70
47	0	M	50.44	0.17	29.71
48	0	M	46.48	0.14	28.18

	J	K	L	M	N
1	Cr2O3	FeO	MnO	MgO	CaO
2					
3	0.06	1.20	0.04	1.96	0.06
4	0.03	1.31	0.03	2.27	0.10
5	0.10	1.54	0.05	2.04	0.05
6	0.00	3.10	0.09	1.61	0.04
7	0.00	2.62	0.03	2.80	0.03
8	0.07	3.18	0.00	3.23	0.03
9	0.07	1.88	0.13	1.86	0.06
10	0.10	1.65	0.00	1.79	0.92
11	0.06	2.42	0.00	2.55	0.03
12	0.04	4.53	0.04	5.75	0.04
13	0.16	1.56	0.01	2.74	0.00
14	0.10	2.74	0.01	2.42	0.00
15	0.10	1.41	0.05	2.07	0.00
16	0.10	0.95	0.00	1.72	0.14
17	0.10	0.95	0.00	1.73	0.01
18	0.01	1.70	0.14	1.36	0.00
19	0.00	1.18	0.01	1.92	0.04
20	0.12	1.80	0.00	2.40	0.00
21	0.17	2.96	0.01	2.40	0.03
22	0.03	2.57	0.00	2.40	0.00
23	0.01	2.92	0.05	2.95	0.03
24	0.06	2.61	0.03	2.06	0.11
25	0.07	3.00	0.08	8.87	0.00
26	0.09	2.78	0.05	6.10	0.00
27	0.04	1.50	0.00	2.14	0.00
28	0.04	1.79	0.04	1.89	0.00
29	0.10	1.61	0.04	1.58	0.00
30	0.06	1.61	0.04	1.82	0.00
31	0.07	1.61	0.00	2.64	0.00
32	0.06	1.61	0.09	1.82	0.00
33	0.06	1.40	0.00	2.06	0.00
34	0.00	0.06	0.00	2.11	0.00
35	0.10	1.39	0.04	1.61	0.00
36	0.10	1.54	0.00	8.41	0.00
37	0.10	7.14	0.00	4.82	0.00
38	0.13	2.60	0.00	4.79	0.00
39	0.06	3.31	0.00	4.91	0.00
40	0.07	2.66	0.01	7.34	0.00
41	0.12	1.34	0.00	2.82	0.00
42	0.03	1.97	0.00	2.82	0.00
43	0.04	2.11	0.00	3.63	0.00
44	0.06	1.11	0.00	2.64	0.00
45	0.12	1.84	0.00	2.69	0.00
46	1.00	2.34	0.00	3.60	0.03
47	0.00	1.83	0.00	3.07	0.00
48	0.07	3.63	0.01	10.18	0.70

	O	P	Q	R	S
1	BaO	Na2O	K2O	SUM	Si
2					
3	0.14	0.04	11.57	93.25	6.575
4	0.10	0.00	10.88	92.15	6.594
5	0.12	0.07	10.69	92.75	6.434
6	0.09	0.12	10.70	90.91	6.628
7	0.15	0.24	10.51	93.26	6.034
8	0.17	0.15	10.38	92.00	5.887
9	0.23	0.12	11.20	94.36	6.124
10	0.30	0.20	10.75	92.64	6.130
11	0.21	0.20	10.68	92.53	5.984
12	0.19	0.12	8.54	91.33	5.565
13	0.07	0.12	10.72	94.78	6.587
14	0.01	0.15	10.44	91.35	6.200
15	0.13	0.15	11.04	95.08	7.206
16	0.07	0.11	10.78	97.48	6.405
17	0.07	0.16	10.76	97.39	6.408
18	0.40	0.16	10.92	96.81	6.275
19	0.08	0.19	11.16	95.50	6.370
20	0.10	0.11	7.12	91.80	6.602
21	0.06	0.12	9.95	93.53	6.538
22	0.05	0.11	10.90	92.72	6.495
23	0.07	0.07	10.90	94.54	6.513
24	0.04	0.09	10.57	93.83	6.587
25	0.13	0.12	5.85	96.91	6.276
26	0.04	0.20	11.05	96.27	6.176
27	0.13	0.15	9.38	93.29	6.469
28	0.09	0.19	10.74	95.59	6.370
29	0.07	0.15	9.79	95.29	6.399
30	0.07	0.16	10.98	96.67	6.343
31	0.10	0.22	10.88	97.39	6.443
32	0.10	0.12	10.38	93.23	6.357
33	0.13	0.12	10.98	97.84	6.463
34	0.06	0.16	11.06	94.41	6.477
35	0.00	0.18	10.82	98.28	6.298
36	0.08	0.04	3.56	92.88	6.038
37	0.03	0.12	9.48	91.83	6.132
38	0.15	0.13	6.60	94.30	6.493
39	0.13	0.12	9.01	93.96	6.112
40	0.00	0.05	7.81	93.12	5.906
41	0.20	0.18	10.33	95.02	6.450
42	0.01	0.07	11.10	95.95	6.574
43	0.05	0.08	10.69	96.16	6.522
44	0.00	0.18	11.28	97.43	6.529
45	0.00	0.03	9.76	96.14	6.753
46	0.00	0.04	10.56	94.15	6.564
47	0.00	0.05	10.84	96.11	6.655
48	0.04	0.03	8.70	98.37	6.088

	T	U	V	W	X
1	Al(T)	Al(O)	Ti	Cr	Fe
2					
3	1.425	3.379	0.030	0.006	0.137
4	1.406	3.372	0.020	0.003	0.151
5	1.565	3.434	0.027	0.011	0.177
6	1.372	3.204	0.840	0.000	0.366
7	1.966	3.376	0.032	0.000	0.302
8	2.113	3.305	0.033	0.008	0.374
9	1.876	3.497	0.031	0.008	0.214
10	1.870	3.446	0.026	0.011	0.192
11	2.016	3.433	0.021	0.007	0.282
12	2.435	3.064	0.020	0.005	0.539
13	1.413	3.148	0.148	0.017	0.175
14	1.800	3.156	0.177	0.011	0.323
15	0.794	3.197	0.026	0.010	0.156
16	1.595	3.577	0.026	0.010	0.103
17	1.592	3.583	0.260	0.010	0.103
18	1.725	3.573	0.035	0.001	0.187
19	1.630	3.495	0.037	0.000	0.131
20	1.398	3.532	0.030	0.013	0.203
21	1.462	3.294	0.023	0.018	0.337
22	1.505	3.286	0.024	0.003	0.297
23	1.487	3.192	0.028	0.001	0.331
24	1.413	3.333	0.150	0.006	0.297
25	1.724	2.842	0.020	0.007	0.324
26	1.824	2.896	0.018	0.010	0.312
27	1.531	3.519	0.022	0.004	0.169
28	1.630	3.495	0.022	0.004	0.199
29	1.601	3.587	0.029	0.010	0.178
30	1.657	3.490	0.049	0.006	0.177
31	1.557	3.371	0.040	0.007	0.176
32	1.643	3.511	0.028	0.006	0.183
33	1.537	3.497	0.017	0.006	0.152
34	1.523	3.547	0.023	0.000	0.007
35	1.702	3.311	0.243	0.010	0.150
36	1.962	3.188	0.024	0.010	0.170
37	1.868	2.747	0.011	0.011	0.857
38	1.507	3.245	0.026	0.014	0.287
39	1.888	3.132	0.027	0.006	0.377
40	2.094	2.995	0.028	0.008	0.304
41	1.550	3.414	0.006	0.013	0.149
42	1.426	3.298	0.017	0.003	0.219
43	1.478	3.234	0.007	0.004	0.234
44	1.471	3.415	0.005	0.006	0.121
45	1.247	3.297	0.056	0.012	0.201
46	1.436	3.003	0.063	0.108	0.266
47	1.345	3.274	0.017	0.000	0.202
48	1.912	2.438	0.034	0.007	0.398

	Y	Z	AA	AB	AC
1	Mn	Mg	Ca	Na	K
2					
3	0.005	0.400	0.009	0.011	2.018
4	0.004	0.466	0.015	0.000	1.913
5	0.006	0.417	0.007	0.019	1.871
6	0.011	0.339	0.006	0.033	1.929
7	0.004	0.576	0.004	0.064	1.850
8	0.000	0.678	0.005	0.041	1.864
9	0.015	0.377	0.009	0.032	1.944
10	0.000	0.370	0.137	0.054	1.903
11	0.000	0.529	0.004	0.054	1.897
12	0.005	1.220	0.006	0.033	1.550
13	0.001	0.548	0.000	0.031	1.835
14	0.001	0.509	0.000	0.041	1.877
15	0.006	0.409	0.000	0.039	1.868
16	0.000	0.332	0.019	0.028	1.781
17	0.000	0.334	0.001	0.040	1.778
18	0.016	0.267	0.000	0.041	1.835
19	0.001	0.381	0.006	0.049	1.894
20	0.000	0.483	0.000	0.029	1.227
21	0.001	0.487	0.004	0.032	1.729
22	0.000	0.494	0.000	0.029	1.921
23	0.006	0.597	0.004	0.018	1.887
24	0.003	0.417	0.016	0.024	1.832
25	0.009	1.708	0.000	0.030	0.964
26	0.006	1.222	0.000	0.052	1.894
27	0.000	0.430	0.000	0.039	1.614
28	0.005	0.375	0.000	0.049	1.822
29	0.004	0.312	0.000	0.038	1.652
30	0.004	0.357	0.000	0.041	1.842
31	0.000	0.513	0.000	0.056	1.810
32	0.010	0.370	0.000	0.032	1.803
33	0.000	0.398	0.000	0.030	1.813
34	0.000	0.420	0.000	0.041	1.883
35	0.004	0.310	0.000	0.045	1.784
36	0.000	1.654	0.000	0.010	0.599
37	0.000	1.031	0.000	0.033	1.735
38	0.000	0.944	0.000	0.033	1.113
39	0.000	0.997	0.000	0.032	1.565
40	0.001	1.493	0.000	0.013	1.360
41	0.000	0.560	0.000	0.047	1.756
42	0.000	0.558	0.000	0.018	1.878
43	0.000	0.716	0.000	0.021	1.805
44	0.000	0.512	0.000	0.045	1.871
45	0.000	0.524	0.000	0.008	1.628
46	0.000	0.730	0.004	0.011	1.832
47	0.000	0.604	0.000	0.013	1.824
48	0.001	1.987	0.098	0.008	1.454

	AD	AE	AF	AG
1	Ba	C	F/M	F/FM
2				
3	0.007	22.000	0.355	0.262
4	0.005	22.000	0.331	0.249
5	0.007	22.000	0.437	0.304
6	0.005	22.000	1.112	0.527
7	0.008	22.000	0.531	0.347
8	0.009	22.000	0.552	0.356
9	0.012	22.000	0.607	0.378
10	0.017	22.000	0.517	0.341
11	0.011	22.000	0.532	0.347
12	0.011	22.000	0.446	0.308
13	0.004	22.000	0.322	0.243
14	0.001	22.000	0.638	0.389
15	0.007	22.000	0.396	0.284
16	0.004	22.000	0.310	0.237
17	0.004	22.000	0.308	0.236
18	0.021	22.000	0.760	0.432
19	0.004	22.000	0.348	0.258
20	0.005	22.000	0.421	0.296
21	0.003	22.000	0.694	0.410
22	0.002	22.000	0.601	0.375
23	0.004	22.000	0.565	0.361
24	0.002	22.000	0.719	0.418
25	0.006	22.000	0.195	0.163
26	0.002	22.000	0.260	0.207
27	0.007	22.000	0.393	0.282
28	0.004	22.000	0.543	0.352
29	0.004	22.000	0.586	0.370
30	0.003	22.000	0.509	0.337
31	0.005	22.000	0.342	0.255
32	0.005	22.000	0.524	0.344
33	0.007	22.000	0.381	0.276
34	0.003	22.000	0.016	0.016
35	0.000	22.000	0.499	0.333
36	0.004	22.000	0.103	0.093
37	0.002	22.000	0.831	0.454
38	0.008	22.000	0.305	0.233
39	0.007	22.000	0.378	0.274
40	0.000	22.000	0.204	0.170
41	0.010	22.000	0.268	0.210
42	0.001	22.000	0.392	0.282
43	0.003	22.000	0.326	0.246
44	0.000	22.000	0.236	0.191
45	0.000	22.000	0.384	0.277
46	0.000	22.000	0.365	0.267
47	0.000	22.000	0.334	0.251
48	0.002	22.000	0.201	0.167

	A	B	C	D
	SAMPLE #	GRAIN #	ROCK TYPE	TRAVERSE
50				
51	RISO-20	1	A	0
52	RISO-20	2	A	0
53	RISO-20	3	A	0
54	RISO-20	4	A	0
55	RS-27-73	1	A	4
56	RS-27-73	2	A	4
57	RS-25-216	1	A	4
58	RS-25-216	2	A	4
59	RS-25-216	3	A	4
60	I020-325E-S	1	A	0
61	I020-325E-S	2	A	0
62	I020-325E-S	3	A	0
63	I152-500E-N	1	A	0
64	I152-500E-N	2	A	0
65	I152-500E-N	3	A	0
66	I152-500E-N	4	A	0
67	I152-500E-N	5	A	0
68	I020-180E-N	1	A	0
69	I020-180E-N	2	A	0
70	I020=180E-N	3	A	0
71	I152-810E-F	1	A	0
72	I152-810E-F	2	A	0
73	I152-810E-F	3	A	0
74	I152-810E-F	4	A	0
75	I152-550E-N	1	A	0
76	I152-550E-N	2	A	0
77	I152-550E-N	3	A	0
78	I152-550E-N	4	A	0
79	I152-660E	1	A	0
80	I152-575E-S	1	A	0
81	I152-575E-S	2	A	0
82	RISO-47	1	AS	3
83	RS-16-655	1	B	2
84	RS-16-655	2	B	2
85	RS-16-655	3	B	2
86	RS-26-145	1	A	1
87	RS-25-80	1	B	4
88	RS-25-171	1	A	4
89	RS-25-171	2	A	4
90	RS-25-171	3	A	4
91	RS-25-171	4	A	4
92	RS-27-174	1	A	4
93	I152-550E-N	1	A	0
94	I152-550E-N	2	A	0
95	I152-550E-N	3	A	0
96	I152-550E-N	4	A	0

	E	F	G	H	I
49	DISTANCE	MODE	SiO2	TiO2	Al2O3
50					
51	0	M	48.26	0.41	31.77
52	0	M	48.62	0.18	32.94
53	0	M	49.48	0.12	32.08
54	0	V	47.06	0.42	32.15
55	430	M	45.71	0.33	27.69
56	430	M	66.31	0.00	24.03
57	201	M	49.41	0.23	31.98
58	201	M	48.45	0.30	33.77
59	201	M	49.80	0.35	32.83
60	0	M	48.48	0.13	29.89
61	0	M	46.84	0.26	29.65
62	0	M	47.98	0.22	30.18
63	0	M	51.27	0.47	28.15
64	0	M	47.62	0.50	28.94
65	0	M	47.32	0.76	28.93
66	0	M	48.60	0.16	29.00
67	0	M	45.48	0.34	29.62
68	0	M	47.48	0.18	28.71
69	0	M	47.30	0.26	29.68
70	0	M	46.59	0.47	28.43
71	0	M	47.64	0.12	28.01
72	0	M	47.47	0.13	30.2[illegible]
73	0	M	42.85	0.19	28.73
74	0	M	47.16	0.25	29.91
75	0	M	47.32	0.25	29.59
76	0	M	48.51	0.23	30.13
77	0	M	48.19	0.17	30.49
78	0	M	47.69	0.25	30.24
79	0	M	44.14	0.16	32.19
80	0	M	46.16	0.21	30.01
81	0	M	46.55	0.29	28.49
82	120	M	51.16	0.11	32.91
83	126	F	56.73	0.28	25.57
84	126	F	49.67	0.20	32.05
85	126	F	66.13	0.16	19.70
86	22	M	49.09	0.55	28.90
87	100	M	51.54	0.62	28.84
88	172	M	46.15	0.20	31.54
89	172	M	43.61	0.20	29.72
90	172	M	48.18	0.45	33.23
91	172	M	47.79	0.20	33.89
92	502	M	47.05	0.13	32.39
93	0	F	53.75	0.45	31.14
94	0	F	50.53	0.27	30.67
95	0	F	55.22	0.41	31.09
96	0	F	50.51	0.10	32.18

	J	K	L	M	N
49	Cr2O3	FeO	MnO	MgO	CaO
50					
51	0.07	1.81	0.00	2.22	0.00
52	0.06	1.23	0.00	1.96	0.00
53	0.09	0.80	0.00	2.02	0.00
54	0.04	1.49	0.00	1.74	0.00
55	0.00	4.76	0.00	3.76	0.00
56	0.00	0.81	0.00	1.92	0.11
57	0.06	2.07	0.00	2.04	0.01
58	0.15	1.43	0.00	1.59	0.00
59	0.10	1.47	0.00	1.86	0.00
60	0.00	1.66	0.00	2.36	0.02
61	0.00	1.61	0.04	2.25	0.03
62	0.00	0.77	0.03	2.20	0.03
63	0.11	1.51	0.00	1.97	0.01
64	0.14	1.77	0.04	2.12	0.00
65	0.05	1.99	0.00	2.60	0.00
66	0.00	0.56	0.00	2.53	0.02
67	0.00	1.98	0.00	3.16	0.00
68	0.00	2.00	0.03	2.65	0.00
69	0.00	1.44	0.03	2.80	0.00
70	0.00	2.82	0.00	3.23	0.00
71	0.02	2.72	0.00	2.58	2.58
72	0.00	1.78	0.00	1.83	0.01
73	0.05	4.35	[illegible]	5.45	0.03
74	0.09	2.34	0.07	1.95	0.00
75	0.00	1.38	0.07	2.34	0.00
76	0.00	1.08	0.00	2.79	0.01
77	0.00	0.66	0.01	2.11	0.00
78	0.04	0.76	0.00	2.16	0.00
79	0.00	2.49	0.07	1.05	0.00
80	0.04	2.77	0.01	1.82	0.06
81	0.00	1.98	0.00	2.35	0.03
82	0.00	1.71	0.00	1.10	0.00
83	0.00	2.70	0.00	4.57	0.00
84	0.00	1.33	0.00	2.66	0.00
85	0.00	1.00	0.00	1.81	0.00
86	0.00	1.90	0.03	2.68	0.00
87	0.07	2.16	0.02	2.25	0.00
88	0.04	2.35	0.00	4.61	0.00
89	0.02	4.25	0.00	9.36	0.00
90	0.00	1.56	0.05	2.36	0.00
91	0.02	1.47	0.08	1.71	0.00
92	0.00	1.98	0.00	2.10	0.01
93	0.05	1.94	0.00	2.75	0.00
94	0.29	2.11	0.03	2.93	0.00
95	0.02	2.04	0.06	3.28	0.00
96	0.04	1.49	0.00	2.07	0.05

	O	P	Q	R	S
49	BaO	Na2O	K2O	SUM	Si
50					
51	0.18	0.23	10.93	95.87	6.416
52	0.00	0.15	11.12	96.26	6.404
53	0.00	0.09	10.40	95.08	6.543
54	0.02	0.23	11.09	94.24	6.360
55	0.06	0.11	7.91	90.33	6.461
56	0.00	1.19	9.87	104.24	7.834
57	0.00	0.12	10.82	96.74	6.486
58	0.05	0.16	10.92	96.81	6.347
59	0.00	0.26	10.56	97.23	6.472
60	0.00	0.20	10.82	93.56	6.582
61	0.00	0.15	10.39	91.22	6.520
62	0.00	0.12	10.37	91.90	6.582
63	0.00	0.20	9.76	93.45	6.887
64	0.00	0.14	10.67	91.94	6.591
65	0.00	0.15	10.33	92.13	6.536
66	0.[illegible]	0.14	9.30	90.31	6.722
67	0.[illegible]	0.19	9.35	90.12	6.399
68	0.00	0.16	10.53	91.74	6.589
69	0.00	0.19	10.14	91.84	6.523
70	0.00	0.17	10.73	92.44	6.473
71	0.00	0.05	11.03	94.75	6.510
72	0.00	0.14	10.39	91.97	6.545
73	0.00	0.13	8.80	90.60	6.106
74	0.00	0.13	10.44	92.34	6.509
75	0.00	0.04	10.78	91.77	6.549
76	0.00	0.05	10.51	93.31	6.569
77	0.00	0.17	10.80	92.60	6.572
78	0.00	0.21	10.08	91.43	6.567
79	0.00	0.20	10.07	90.35	6.233
80	0.00	0.23	10.22	91.53	6.444
81	0.00	0.12	10.24	90.05	6.575
82	0.00	0.07	9.29	96.35	6.631
83	0.00	0.02	8.25	98.12	7.195
84	0.00	0.13	9.42	95.46	6.523
85	0.00	0.12	7.51	96.43	8.277
86	0.00	0.05	9.22	92.42	6.681
87	0.00	0.12	9.94	95.56	6.801
88	0.00	0.04	8.77	93.70	6.233
89	0.00	0.25	6.66	94.07	5.919
90	0.00	0.13	10.00	95.96	6.341
91	0.00	0.13	9.90	95.18	6.329
92	0.00	0.13	10.50	94.29	6.343
93	0.00	0.12	5.13	95.33	6.858
94	0.00	0.04	9.02	95.89	6.617
95	0.00	0.09	4.66	96.87	6.912
96	0.00	0.12	8.92	95.48	6.602

	T	U	V	W	X
49	Al(T)	Al(O)	Ti	Cr	Fe
50					
51	1.584	3.393	0.041	0.007	0.201
52	1.596	3.517	0.018	0.006	0.135
53	1.457	3.541	0.012	0.009	0.088
54	1.640	3.480	0.043	0.004	0.168
55	1.539	3.074	0.035	0.000	0.563
56	0.166	3.179	0.000	0.000	0.080
57	1.514	3.433	0.023	0.006	0.277
58	1.653	3.560	0.029	0.016	0.157
59	1.528	3.499	0.034	0.010	0.160
60	1.418	3.364	0.013	0.000	0.188
61	1.480	3.384	0.027	0.000	0.167
62	1.418	3.461	0.023	0.000	0.088
63	1.113	3.342	0.048	0.012	0.170
64	1.409	3.311	0.052	0.015	0.205
65	1.467	3.245	0.079	0.005	0.230
66	1.278	3.449	0.017	0.000	0.065
67	1.601	3.310	0.036	0.000	0.233
68	1.411	3.285	0.019	0.000	0.232
69	1.477	3.346	0.027	0.000	0.166
70	1.527	3.127	0.049	0.000	0.328
71	1.490	3.021	0.012	0.002	0.311
72	1.455	3.455	0.014	0.000	0.205
73	1.894	2.929	0.021	0.006	0.518
74	1.491	3.373	0.026	0.010	0.270
75	1.451	3.375	0.026	0.000	0.160
76	1.431	3.376	0.024	0.000	0.122
77	1.428	3.472	0.018	0.000	0.075
78	1.433	3.474	0.026	0.004	0.088
79	1.767	3.592	0.017	0.000	0.294
80	1.556	3.380	0.022	0.004	0.323
81	1.425	3.317	0.031	0.000	0.234
82	1.369	3.657	0.011	0.000	0.185
83	0.805	3.017	0.027	0.000	0.286
84	1.477	3.482	0.020	0.000	0.146
85	0.000	2.905	0.015	0.000	0.105
86	1.319	3.315	0.057	0.000	0.216
87	1.199	3.285	0.062	0.007	0.238
88	1.767	3.253	0.020	0.004	0.265
89	2.081	2.672	0.021	0.002	0.482
90	1.659	3.494	0.045	0.000	0.172
91	1.671	3.618	0.020	0.002	0.163
92	1.657	3.488	0.013	0.000	0.223
93	1.142	3.541	0.044	0.005	0.207
94	1.383	3.350	0.027	0.030	0.231
95	1.088	3.497	0.039	0.002	0.214
96	1.398	3.559	0.010	0.004	0.163

	Y	Z	AA	AB	AC
49	Mn	Mg	Ca	Na	K
50					
51	0.000	0.440	0.000	0.059	1.853
52	0.000	0.385	0.000	0.038	1.868
53	0.000	0.398	0.000	0.024	1.754
54	0.000	0.350	0.000	0.060	1.912
55	0.000	0.792	0.000	0.030	1.426
56	0.000	0.338	0.014	0.273	1.487
57	0.000	0.399	0.001	0.031	1.812
58	0.000	0.310	0.000	0.041	1.825
59	0.000	0.360	0.000	0.066	1.750
60	0.000	0.478	0.003	0.053	1.874
61	0.005	0.467	0.004	0.150	1.845
62	0.003	0.450	0.004	0.120	1.814
63	0.000	0.394	0.001	0.200	1.672
64	0.005	0.437	0.000	0.140	1.884
65	0.000	0.535	0.000	0.150	1.820
66	0.000	0.522	0.003	0.140	1.641
67	0.000	0.663	0.000	0.190	1.678
68	0.004	0.548	0.000	0.160	1.864
69	0.004	0.576	0.000	0.051	1.784
70	0.000	0.669	0.000	0.046	1.901
71	0.000	0.526	0.378	0.013	1.923
72	0.000	0.376	0.001	0.037	1.827
73	0.002	1.157	0.005	0.036	1.599
74	0.008	0.401	0.000	0.035	1.838
75	0.008	0.483	0.000	0.011	1.903
76	0.000	0.563	0.001	0.013	1.815
77	0.001	0.429	0.000	0.045	1.879
78	0.000	0.443	0.000	0.056	1.770
79	0.008	0.221	0.000	0.055	1.815
80	0.001	0.379	0.009	0.062	1.820
81	0.000	0.495	0.005	0.033	1.845
82	0.000	0.212	0.000	0.018	1.536
83	0.000	0.864	0.000	0.005	1.335
84	0.000	0.521	0.000	0.033	1.578
85	0.000	0.338	0.000	0.029	1.199
86	0.003	0.544	0.000	0.013	1.600
87	0.002	0.443	0.000	0.031	1.673
88	0.000	0.928	0.000	0.010	1.511
89	0.000	1.893	0.000	0.066	1.153
90	0.006	0.463	0.000	0.033	1.679
91	0.009	0.338	0.000	0.031	1.672
92	0.000	0.422	0.001	0.034	1.805
93	0.000	0.523	0.000	0.030	0.835
94	0.003	0.572	0.000	0.010	1.507
95	0.006	0.612	0.000	0.022	0.744
96	0.000	0.403	0.007	0.030	1.487

	AD	AE	AF	AG
49	Ba	C	F/M	F/FM
50				
51	0.009	22.000	0.457	0.314
52	0.000	22.000	0.352	0.260
53	0.000	22.000	0.222	0.182
54	0.001	22.000	0.480	0.325
55	0.004	22.000	0.710	0.415
56	0.000	22.000	0.237	0.191
57	0.000	22.000	0.569	0.363
58	0.002	22.000	0.505	0.335
59	0.000	22.000	0.443	0.307
60	0.000	22.000	0.395	0.283
61	0.000	22.000	0.412	0.292
62	0.000	22.000	0.204	0.170
63	0.000	22.000	0.430	0.301
64	0.000	22.000	0.479	0.324
65	0.000	22.000	0.429	0.300
66	0.000	22.000	0.124	0.110
67	0.000	22.000	0.352	0.260
68	0.000	22.000	0.430	0.301
69	0.000	22.000	0.295	0.228
70	0.000	22.000	0.490	0.329
71	0.000	22.000	0.592	0.372
72	0.000	22.000	0.546	0.353
73	0.000	22.000	0.450	0.310
74	0.000	22.000	0.694	0.410
75	0.000	22.000	0.348	0.258
76	0.000	22.000	0.217	0.178
77	0.000	22.000	0.178	0.151
78	0.000	22.000	0.197	0.165
79	0.000	22.000	1.368	0.578
80	0.000	22.000	0.857	0.462
81	0.000	22.000	0.473	0.321
82	0.000	22.000	0.872	0.466
83	0.000	22.000	0.331	0.249
84	0.000	22.000	0.281	0.219
85	0.000	22.000	0.310	0.237
86	0.000	22.000	0.404	0.288
87	0.000	22.000	0.544	0.352
88	0.000	22.000	0.286	0.222
89	0.000	22.000	0.255	0.203
90	0.000	22.000	0.383	0.277
91	0.000	22.000	0.509	0.337
92	0.000	22.000	0.529	0.346
93	0.000	22.000	0.396	0.284
94	0.000	22.000	0.410	0.291
95	0.000	22.000	0.359	0.264
96	0.000	22.000	0.404	0.288

	A	B	C	D
97	SAMPLE #	GRAIN #	ROCK TYPE	TRAVERSE
98				
99	I152-575E-S	1	A	0
100	I152-575E-S	2	A	0
101	I152-500E-N	1	A	0
102	I152-500E-N	2	A	0
103	I152-500E-N	3	A	0
104	I152-400E-S	1	A	0
105	I020-710E-S	1	A	0
106	I020-320E-S	1	A	0
107	I020-710E-S	2	A	0
108	I020-160E-N	1	A	0
109	I020-160E-N	2	A	0

	E	F	G	H	I
97	DISTANCE	MODE	SiO2	TiO2	Al2O3
98					
99	0	M	49.52	0.45	33.24
100	0	M	50.90	0.15	30.69
101	0	M	50.33	1.08	29.12
102	0	M	47.84	1.04	28.66
103	0	M	50.03	0.18	30.46
104	0	M	52.43	0.65	32.27
105	0	M	47.83	0.43	25.95
106	0	V	48.49	0.37	27.56
107	0	V	48.16	0.41	27.67
108	0	V	45.28	0.22	24.64
109	0	V	48.06	0.11	25.38

	J	K	L	M	N
97	Cr2O3	FeO	MnO	MgO	CaO
98					
99	0.00	1.03	0.00	1.71	0.01
100	0.02	0.88	0.00	2.16	0.06
101	0.00	1.86	0.02	3.13	0.02
102	0.00	1.97	0.00	2.43	0.01
103	0.11	2.00	0.00	2.60	0.02
104	0.00	2.17	0.00	2.02	0.07
105	0.02	1.39	0.06	2.21	0.02
106	0.04	1.47	0.00	1.73	0.02
107	0.06	1.35	0.00	1.79	0.00
108	0.00	1.04	0.00	1.79	0.05
109	0.00	1.07	0.01	1.94	0.01

	O	P	Q	R	S
97	BaO	Na2O	K2O	SUM	Si
98					
99	0.00	0.13	8.84	94.93	6.497
100	0.00	0.17	7.72	92.75	6.769
101	0.00	0.05	8.33	93.94	6.695
102	0.00	0.05	8.89	90.89	6.623
103	0.00	0.06	9.16	94.62	6.639
104	0.00	0.13	7.45	97.19	6.680
105	0.00	0.07	10.57	88.55	6.852
106	0.00	0.16	11.02	90.86	6.780
107	0.00	0.17	11.02	90.63	6.751
108	0.00	0.26	10.04	83.32	6.884
109	0.00	0.14	10.60	87.32	6.962

	T	U	V	W	X
97	Al(T)	Al(O)	Ti	Cr	Fe
98					
99	1.503	3.636	0.045	0.000	0.113
100	1.231	3.579	0.015	0.002	0.098
101	1.305	3.259	0.108	0.000	0.207
102	1.377	3.298	0.108	0.000	0.228
103	1.361	3.401	0.018	0.012	0.222
104	1.320	3.525	0.062	0.000	0.231
105	1.148	3.233	0.047	0.002	0.167
106	1.222	3.321	0.039	0.004	0.172
107	1.249	3.322	0.044	0.007	0.158
108	1.116	3.298	0.025	0.000	0.132
109	1.038	3.294	0.012	0.000	0.130

	Y	Z	AA	AB	AC
97	Mn	Mg	Ca	Na	K
98					
99	0.000	0.334	0.001	0.033	1.479
100	0.000	0.428	0.009	0.044	1.309
101	0.002	0.621	0.003	0.013	1.413
102	0.000	0.501	0.001	0.013	1.570
103	0.000	0.514	0.003	0.015	1.550
104	0.000	0.384	0.010	0.032	1.211
105	0.007	0.472	0.003	0.019	1.931
106	0.000	0.361	0.003	0.043	1.965
107	0.000	0.374	0.000	0.046	1.970
108	0.000	0.406	0.008	0.077	1.947
109	0.001	0.419	0.002	0.039	1.959

	AD	AE	AF	AG
97	Ba	C	F/M	F/FM
98				
99	0.000	22.000	0.338	0.253
100	0.000	22.000	0.229	0.186
101	0.000	22.000	0.337	0.252
102	0.000	22.000	0.455	0.313
103	0.000	22.000	0.432	0.301
104	0.000	22.000	0.603	0.376
105	0.000	22.000	0.368	0.269
106	0.000	22.000	0.477	0.323
107	0.000	22.000	0.423	0.297
108	0.000	22.000	0.326	0.246
109	0.000	22.000	0.312	0.238

APPENDIX E-3: CARBONATE MINERALS

	A	B	C	D
1	SAMPLE #	GRAIN #	ROCK TYPE	TRAVERSE
2				
3	RISO-43	1	B	3
4	RISO-49	2	B	3
5	RISO-49	3	B	3
6	RISO-49	4	B	3
7	RISO-47	1	AS	3
8	RISO-47	2	AS	3
9	RISO-45	1	T	3
10	RS-26-113	1	B	1
11	RS-26-113	2	B	1
12	RS-26-113	3	B	1
13	RS-26-191	1	T	1
14	RS-26-191	2	T	1
15	RS-26-191	3	T	1
16	RS-26-191	4	T	1
17	RS-26-191	5	T	1
18	RS-26-166	1	B	1
19	RS-26-166	2	B	1
20	RS-26-166	3	B	1
21	RISO-46	1	P	3
22	RISO-46	2	P	3
23	RISO-46	3	P	3
24	RISO-46	4	P	3
25	RS-26-259	1	P	1
26	RS-26-259	2	P	1
27	RS-26-259	3	P	1
28	RS-25-135	1	A	4
29	RS-25-135	2	A	4
30	RS-25-135	3	A	4
31	RS-16-849	1	P	2
32	RS-16-631	1	B	2
33	RS-16-631	2	B	2
34	RS-16-631	3	B	2
35	RS-16-790	1	A	2
36	RISO-16	1	AS	0
37	RISO-18	1	AS	0
38	RISO-18	2	AS	0
39	RISO-18	3	AS	0
40	RISO-22	1	AN	0
41	RISO-22	2	AN	0
42	RS-16-482	1	P	2
43	RS-16-482	2	P	2
44	RS-16-482	3	P	2
45	RS-16-482	4	P	2
46	RS-16-870	1	T	2
47	RS-24-193	1	A	4
48	RS-24-193	2	A	4

	E	F	G	H	I
1	DISTANCE	MODE	MgO	CaO	MnO
2					
3	72	M	22.10	29.98	0.00
4	72	M	12.04	27.17	0.19
5	72	M	19.07	29.96	0.14
6	72	M	19.27	31.90	0.00
7	120	V	17.44	29.80	0.08
8	120	V	17.[illegible]	30.51	0.00
9	230	M	21.40	30.43	0.57
10	0	M	19.66	31.35	0.37
11	0	M	19.70	31.73	0.45
12	0	V	18.77	30.93	0.40
13	55	M	18.57	30.12	0.17
14	55	M	22.03	30.44	0.03
15	55	M	20.34	29.41	0.17
16	55	M	19.50	30.97	0.22
17	55	M	20.01	30.16	0.17
18	37	C	19.33	30.26	0.15
19	37	C	22.20	32.34	0.05
20	37	M	18.80	31.51	0.32
21	260	M	40.34	0.08	0.21
22	260	M	21.40	31.41	0.27
23	260	M	41.67	0.43	0.58
24	260	M	41.20	0.11	0.39
25	101	M	43.19	0.15	0.06
26	101	M	44.07	0.15	0.08
27	101	M	43.07	0.21	0.09
28	0	M	18.75	24.05	0.17
29	0	M	18.49	29.10	0.35
30	0	M	16.90	29.63	0.44
31	28	M	21.32	31.56	0.15
32	138	M	19.37	30.01	0.65
33	138	M	19.46	30.83	0.14
34	138	M	18.79	30.18	0.09
35	58	M	19.68	30.18	0.30
36	0	M	0.02	55.68	0.08
37	0	M	18.32	26.92	0.89
38	0	C	17.34	26.44	1.14
39	0	C	17.62	30.05	1.08
40	0	M	17.97	30.39	0.00
41	0	C	19.02	30.15	1.01
42	212	C	20.94	32.47	0.03
43	212	C	17.53	30.99	0.00
44	212	C	21.88	32.48	0.00
45	212	M	36.68	0.00	0.23
46	16	C	45.35	0.13	0.00
47	370	M	18.22	30.37	1.15
48	370	M	20.81	21.78	0.79

	J	K	L	M	N
1	FeO	Mg	Ca	Mn	Fe
2					
3	0.04	1.01	0.99	0.00	0.00
4	7.65	0.67	1.09	0.01	0.24
5	2.75	0.90	1.02	0.00	0.07
6	1.92	0.89	1.06	0.00	0.05
7	7.98	0.80	0.99	0.00	0.21
8	1.98	0.87	1.08	0.00	0.05
9	2.16	0.96	0.98	0.01	0.05
10	5.17	0.87	0.99	0.01	0.13
11	5.74	0.86	0.99	0.01	0.14
12	5.81	0.84	1.00	0.01	0.15
13	6.16	0.85	0.99	0.00	0.16
14	2.52	0.97	0.97	0.00	0.06
15	3.66	0.93	0.97	0.00	0.09
16	5.85	0.86	0.99	0.01	0.15
17	4.03	0.91	0.98	0.00	0.10
18	5.70	0.87	0.98	0.00	0.14
19	1.58	0.96	1.00	0.00	0.04
20	5.35	0.84	1.01	0.01	0.13
21	4.63	1.87	0.00	0.01	0.12
22	1.81	0.95	1.00	0.01	0.04
23	6.84	1.81	0.01	0.01	0.17
24	6.22	1.83	0.00	0.01	0.16
25	5.94	1.85	0.00	0.00	0.14
26	5.92	1.85	0.00	0.00	0.14
27	6.51	1.84	0.01	0.00	0.16
28	2.15	1.00	0.93	0.01	0.06
29	4.76	0.87	0.99	0.01	0.13
30	5.29	0.82	1.03	0.01	0.14
31	2.06	0.94	1.00	0.00	0.05
32	4.03	0.89	0.99	0.02	0.10
33	3.97	0.89	1.01	0.00	0.10
34	4.53	0.87	1.00	0.00	0.12
35	3.49	0.90	1.00	0.01	0.09
36	0.18	0.00	1.99	0.00	0.01
37	3.06	0.92	0.97	0.03	0.09
38	8.89	0.83	0.91	0.03	0.24
39	6.85	0.81	0.99	0.03	0.18
40	0.00	0.90	1.10	0.00	0.00
41	3.91	0.88	1.00	0.03	0.10
42	1.67	0.93	1.03	0.00	0.04
43	1.88	0.86	1.09	0.00	0.05
44	1.88	0.95	1.01	0.00	0.05
45	14.43	1.63	0.00	0.01	0.36
46	2.48	1.94	0.00	0.00	0.06
47	4.00	0.85	1.02	0.03	0.10
48	4.28	1.06	0.80	0.02	0.12

	A	B	C	D
49	SAMPLE #	GRAIN #	ROCK TYPE	TRAVERSE
50				
51	RS-24-193	3	A	4
52	RS-24-193	4	A	4
53	RS-25-256	1	B	4
54	RS-16-563	1	T	2
55	RS-16-563	2	T	2
56	RS-16-563	3	T	2
57	RISO-48	1	AS	3
58	RISO-48	2	AS	3
59	RS-27-21	1	B	4
60	RS-27-21	2	B	4
61	RS-27-21	3	B	4
62	RS-27-21	4	B	4
63	RISO-27	1	AS	0
64	RS-27-277	1	B	4
65	RS-27-277	2	B	4
66	RS-27-277	3	B	4
67	RS-27-277	4	B	4
68	RS-27-277	5	B	4
69	RS-25-335	1	B	4
70	RS-25-335	2	B	4
71	RS-25-335	3	B	4
72	RS-25-335	4	B	4

	E	F	G	H	I
49	DISTANCE	MODE	MgO	CaO	MnO
50					
51	370	M	2.65	26.82	0.70
52	370	M	17.94	29.99	0.76
53	230	C	20.61	31.91	0.57
54	173	M	19.65	31.81	0.36
55	173	M	19.98	32.36	0.36
56	173	M	20.23	32.36	0.36
57	98	M	20.03	32.55	0.70
58	98	M	20.51	31.67	0.81
59	530	M	18.65	30.53	1.05
60	530	M	17.97	30.65	0.52
61	530	M	19.25	30.58	0.06
62	530	M	18.22	30.50	0.90
63	0	M	20.46	31.45	0.83
64	570	C	16.75	27.83	0.41
65	570	C	18.39	31.39	1.17
66	570	V	12.72	29.67	0.85
67	570	C	16.55	30.23	0.37
68	570	V	20.58	32.16	0.43
69	288	C	19.53	30.64	0.00
70	288	C	19.78	31.70	0.09
71	288	C	21.44	33.03	0.00
72	288	M	20.74	33.25	0.06

	J	K	L	M	N
49	FeO	Mg	Ca	Mn	Fe
50					
51	6.33	0.71	1.07	0.02	0.20
52	4.68	0.84	1.01	0.02	0.12
53	2.10	0.92	1.02	0.01	0.05
54	4.14	0.87	1.02	0.01	0.10
55	4.28	0.87	1.01	0.01	0.10
56	3.94	0.88	1.01	0.01	0.10
57	3.63	0.87	1.02	0.02	0.09
58	3.59	0.90	1.00	0.02	0.09
59	3.74	0.86	1.01	0.03	0.10
60	4.99	0.83	1.02	0.01	0.13
61	3.73	0.89	1.01	0.00	0.10
62	5.44	0.83	1.00	0.02	0.14
63	1.54	0.[illegible]2	1.02	0.02	0.04
64	9.37	0.79	0.95	0.01	0.25
65	6.46	0.81	1.00	0.03	0.16
66	8.77	0.64	1.08	0.02	0.25
67	4.27	0.81	1.06	0.01	0.12
68	3.58	0.90	1.01	0.01	0.09
69	4.46	0.89	1.00	0.00	0.11
70	4.69	0.87	1.01	0.00	0.12
71	1.40	0.93	1.03	0.00	0.03
72	3.92	0.88	1.02	0.00	0.09

APPENDIX E-4: TALC

	A	B	C	D	E
1	SAMPLE #	GRAIN #	ROCK TYPE	TRAVERSE	DISTANCE
2					
3	RISO-50	1	T	3	50
4	RISO-50	2	T	3	50
5	RISO-50	3	T	3	50
6	RISO-50	4	T	3	50
7	RISO-49	1	B	3	72
8	RISO-51	1	T	3	0
9	RISO-45	1	T	3	230
10	RISO-45	2	T	3	230
11	RISO-45	3	T	3	230
12	RS-26-191	1	T	1	55
13	RS-26-191	2	T	1	55
14	RS-26-191	3	T	1	55
15	RS-26-166	1	B	1	37
16	RS-26-259	1	P	1	101
17	RS-26-259	2	P	1	101
18	RS-16-631	1	B	2	138
19	RS-16-849	1	P	2	28
20	RS-16-482	1	P	2	212
21	RS-16-482	2	P	2	212
22	RS-16-482	3	P	2	212
23	RS-16-870	1	T	2	16
24	RS-16-870	2	T	2	16
25	RS-16-870	3	T	2	16
26	RS-16-563	1	T	2	173
27	RS-16-563	2	T	2	173
28	RS-27-277	1	B	4	570
29	RS-27-277	2	B	4	570
30	RS-27-277	3	B	4	570
31	RS-27-277	4	B	4	570
32	RISO-45	4	T	3	230
33	RISO-46	1	P	3	260
34	RISO-46	2	P	3	260
35	RISO-46	3	P	3	260
36	RISO-50	5	T	3	50
37	RS-16-482	4	P	2	212
38	RS-24-193	1	A	4	370
39	RS-27-277	5	B	4	570
40	RISO-45	4	T	3	230
41	RISO-46	1	P	3	260
42	RISO-46	2	P	3	260
43	RISO-46	3	P	3	260
44	RISO-50	5	T	3	50
45	RS-16-482	4	P	2	212
46	RS-24-193	1	A	4	370
47	RS-27-277	4	B	4	570

	F	G	H	I	J
1	MODE	SiO2	TiO2	Al2O3	Cr2O3
2					
3	M	60.28	0.02	0.08	0.00
4	M	60.17	0.01	0.15	0.00
5	M	58.91	0.00	0.06	0.00
6	M	59.25	0.02	0.17	0.06
7	M	59.27	0.00	0.00	0.06
8	M	60.53	0.00	0.00	0.00
9	M	59.36	0.00	0.00	0.07
10	M	59.66	0.03	0.00	0.01
11	M	59.83	0.07	0.00	0.06
12	M	59.59	0.00	0.00	0.04
13	M	59.91	0.03	0.00	0.07
14	M	59.51	0.02	0.00	0.00
15	M	59.02	0.00	0.00	0.06
16	M	60.96	0.05	0.00	0.00
17	M	60.08	0.06	0.00	0.00
18	M	58.42	0.00	1.81	0.06
19	M	60.45	0.02	0.00	0.00
20	F	60.30	0.00	0.00	0.04
21	F	60.28	0.00	0.11	0.06
22	V	61.69	0.00	0.00	0.06
23	F	60.34	0.00	0.00	0.58
24	F	59.81	0.00	0.00	0.12
25	M	58.89	0.00	0.00	0.09
26	M	60.75	0.00	0.00	0.06
27	M	59.66	0.00	0.00	0.06
28	M	60.68	0.00	0.00	0.00
29	M	61.39	0.00	0.00	0.00
30	F	61.09	0.00	0.00	0.19
31	V	63.27	0.00	0.00	0.00
32	M	56.69	0.00	0.64	0.00
33	M	62.85	0.00	0.09	0.00
34	M	59.70	0.00	0.09	0.00
35	M	60.23	0.00	0.37	0.03
36	M	58.76	0.00	0.24	0.00
37	F	57.13	0.00	0.00	0.00
38	M	60.04	0.00	0.11	0.04
39	M	57.49	0.03	0.38	0.02
40	?	56.69	0.00	0.64	0.00
41	?	62.85	0.00	0.09	0.00
42	?	59.70	0.00	0.09	0.00
43	?	60.23	0.00	0.37	0.03
44	?	58.76	0.00	0.24	0.00
45	?	57.13	0.00	0.00	0.00
46	?	60.04	0.00	0.11	0.04
47	?	57.49	0.03	0.38	0.02

	K	L	M	N	O
1	FeO	MnO	MgO	CaO	BaO
2					
3	5.36	0.08	26.69	0.03	0.06
4	5.38	0.07	27.29	0.07	0.09
5	5.70	0.00	27.89	0.20	0.06
6	4.57	0.00	27.74	0.35	0.04
7	3.95	0.06	28.14	0.03	0.10
8	1.86	0.00	29.91	0.53	0.06
9	3.47	0.00	28.39	0.00	0.03
10	3.54	0.01	28.52	0.00	0.00
11	3.51	0.01	28.25	0.00	0.02
12	3.56	0.00	28.57	0.00	0.00
13	3.41	0.04	28.66	0.00	0.00
14	3.37	0.00	29.20	0.00	0.02
15	4.91	0.03	27.69	0.00	0.00
16	1.31	0.00	28.75	0.06	0.01
17	1.29	0.00	29.31	0.04	0.08
18	5.63	0.06	25.73	0.13	0.04
19	3.19	0.00	29.10	0.00	0.01
20	2.84	0.00	25.58	0.00	0.04
21	2.46	0.03	28.88	0.00	0.00
22	2.34	0.00	28.96	0.00	0.00
23	2.22	0.01	28.67	0.00	0.00
24	2.70	0.00	27.77	0.00	0.00
25	2.06	0.00	29.45	0.00	0.00
26	3.56	0.00	28.22	0.00	0.00
27	3.28	0.00	27.74	0.00	0.00
28	1.98	0.00	27.97	0.06	0.00
29	2.07	0.00	28.17	0.06	0.00
30	1.98	0.00	28.48	0.01	0.00
31	2.31	0.00	29.21	0.00	0.00
32	3.45	0.00	27.07	0.00	0.00
33	0.88	0.00	28.92	0.00	0.00
34	1.07	0.00	28.94	0.00	0.00
35	0.95	0.00	28.16	0.00	0.00
36	4.80	0.00	26.20	0.00	0.00
37	2.63	0.00	26.29	0.00	0.00
38	5.91	0.01	26.29	0.06	0.00
39	2.04	0.02	27.73	0.04	0.00
40	3.45	0.00	27.07	0.00	0.00
41	0.88	0.00	28.92	0.00	0.00
42	1.07	0.00	28.94	0.00	0.00
43	0.95	0.00	28.16	0.00	0.00
44	4.80	0.00	26.20	0.00	0.00
45	2.63	0.00	26.29	0.00	0.00
46	5.91	0.01	26.29	0.06	0.00
47	2.04	0.02	27.73	0.04	0.00

	P	Q	R	S	T
1	Na2O	K2O	SUM	Si	Al(T)
2					
3	0.00	0.02	92.61	8.031	0.000
4	0.04	0.10	93.37	7.971	0.023
5	0.01	0.04	92.87	7.877	0.009
6	0.00	0.04	92.24	7.925	0.027
7	0.00	0.02	91.63	7.951	0.000
8	0.00	0.02	92.91	7.936	0.000
9	0.07	0.00	91.39	7.958	0.000
10	0.04	0.01	91.82	7.959	0.000
11	0.09	0.02	91.86	7.978	0.000
12	0.07	0.00	91.83	7.952	0.000
13	0.05	0.01	92.18	7.959	0.000
14	0.07	0.01	92.20	7.912	0.000
15	0.07	0.00	91.78	7.938	0.000
16	0.00	0.01	91.15	8.078	0.000
17	0.00	0.04	90.91	8.005	0.000
18	0.00	0.01	91.89	7.866	0.134
19	0.00	0.00	92.77	7.965	0.000
20	0.00	0.00	91.80	8.009	0.000
21	0.00	0.00	91.82	7.991	0.009
22	0.00	0.00	93.05	8.051	0.000
23	0.10	0.00	91.92	7.994	0.000
24	0.00	0.00	90.40	8.052	0.000
25	0.00	0.00	90.49	7.924	0.000
26	0.05	0.00	92.64	8.019	0.000
27	0.01	0.00	90.75	8.028	0.000
28	0.00	0.00	90.69	8.102	0.000
29	0.00	0.00	91.69	8.109	0.000
30	0.03	0.00	92.01	8.050	0.000
31	0.00	0.00	94.79	8.092	0.000
32	0.02	0.02	87.89	7.905	0.095
33	0.04	0.04	92.82	8.145	0.000
34	0.04	0.04	89.88	8.025	0.000
35	0.03	0.05	89.82	8.081	0.000
36	0.02	0.01	90.03	8.028	0.000
37	0.03	0.00	86.08	8.074	0.000
38	0.09	0.00	92.55	8.024	0.000
39	0.04	0.00	87.79	7.962	0.038
40	0.02	0.02	87.89	7.905	0.095
41	0.04	0.04	92.82	8.145	0.000
42	0.04	0.04	89.88	8.025	0.000
43	0.03	0.05	89.82	8.081	0.000
44	0.02	0.01	90.03	8.028	0.000
45	0.03	0.00	86.08	8.074	0.000
46	0.09	0.00	92.55	8.024	0.000
47	0.04	0.00	87.79	7.962	0.038

	U	V	W	X	Y
1	AL(O)	Ti	Cr	Fe	Mn
2					
3	0.013	0.002	0.000	0.597	0.009
4	0.000	0.001	0.000	0.596	0.008
5	0.000	0.000	0.000	0.637	0.000
6	0.000	0.002	0.006	0.511	0.000
7	0.000	0.000	0.006	0.443	0.007
8	0.000	0.000	0.000	0.204	0.000
9	0.000	0.000	0.007	0.389	0.000
10	0.000	0.003	0.001	0.395	0.001
11	0.000	0.007	0.006	0.391	0.001
12	0.000	0.000	0.004	0.397	0.000
13	0.000	0.003	0.007	0.379	0.005
14	0.000	0.002	0.000	0.375	0.000
15	0.000	0.000	0.006	0.552	0.003
16	0.000	0.005	0.000	0.145	0.000
17	0.000	0.006	0.000	0.144	0.000
18	0.154	0.000	0.006	0.634	0.007
19	0.000	0.002	0.000	0.351	0.000
20	0.000	0.000	0.004	0.315	0.000
21	0.000	0.000	0.006	0.273	0.003
22	0.000	0.000	0.006	0.255	0.000
23	0.000	0.000	0.061	0.246	0.001
24	0.000	0.000	0.013	0.304	0.000
25	0.000	0.000	0.010	0.232	0.000
26	0.000	0.000	0.006	0.393	0.000
27	0.000	0.000	0.006	0.369	0.000
28	0.000	0.000	0.000	0.221	0.000
29	0.000	0.000	0.000	0.229	0.000
30	0.036	0.000	0.020	0.218	0.000
31	0.000	0.000	0.000	0.247	0.000
32	0.010	0.000	0.000	0.402	0.000
33	0.014	0.000	0.000	0.095	0.000
34	0.014	0.000	0.000	0.120	0.000
35	0.058	0.000	0.003	0.107	0.000
36	0.039	0.000	0.000	0.548	0.000
37	0.000	0.000	0.000	0.311	0.000
38	0.017	0.000	0.004	0.661	0.001
39	0.024	0.003	0.002	0.236	0.002
40	0.010	0.000	0.000	0.402	0.000
41	0.014	0.000	0.000	0.095	0.000
42	0.014	0.000	0.000	0.120	0.000
43	0.058	0.000	0.003	0.107	0.000
44	0.039	0.000	0.000	0.548	0.000
45	0.000	0.000	0.000	0.311	0.000
46	0.017	0.000	0.004	0.661	0.001
47	0.024	0.003	0.002	0.236	0.002

	Z	AA	AB	AC	AD
1	Mg	Ca	Na	K	Ba
2					
3	5.300	0.004	0.000	0.003	0.003
4	5.388	0.010	0.010	0.017	0.005
5	5.558	0.029	0.003	0.007	0.003
6	5.530	0.050	0.000	0.007	0.002
7	5.627	0.004	0.000	0.003	0.005
8	5.845	0.074	0.000	0.003	0.003
9	5.673	0.000	0.018	0.000	0.002
10	5.671	0.000	0.010	0.002	0.000
11	5.614	0.000	0.023	0.003	0.001
12	5.683	0.000	0.018	0.000	0.000
13	5.675	0.000	0.013	0.002	0.000
14	5.787	0.000	0.013	0.002	0.001
15	5.551	0.000	0.018	0.000	0.000
16	5.679	0.009	0.000	0.002	0.001
17	5.821	0.006	0.000	0.007	0.004
18	5.164	0.019	0.000	0.002	0.002
19	5.715	0.000	0.000	0.000	0.000
20	5.658	0.000	0.000	0.000	0.002
21	5.706	0.000	0.000	0.000	0.000
22	5.633	0.000	0.000	0.000	0.000
23	5.661	0.000	0.026	0.000	0.000
24	5.573	0.000	0.000	0.000	0.000
25	5.906	0.000	0.000	0.000	0.000
26	5.552	0.000	0.013	0.000	0.000
27	5.564	0.000	0.003	0.000	0.000
28	5.566	0.009	0.000	0.000	0.000
29	5.546	0.008	0.000	0.000	0.000
30	5.594	0.001	0.008	0.000	0.000
31	5.568	0.000	0.000	0.000	0.000
32	5.626	0.000	0.005	0.004	0.000
33	5.586	0.000	0.010	0.007	0.000
34	5.799	0.000	0.010	0.007	0.000
35	5.631	0.000	0.008	0.009	0.000
36	5.335	0.000	0.005	0.002	0.000
37	5.538	0.000	0.008	0.000	0.000
38	5.237	0.009	0.023	0.000	0.000
39	5.724	0.006	0.011	0.000	0.000
40	5.626	0.000	0.005	0.004	0.000
41	5.586	0.000	0.010	0.007	0.000
42	5.799	0.000	0.010	0.007	0.000
43	5.631	0.000	0.008	0.009	0.000
44	5.335	0.000	0.005	0.002	0.000
45	5.538	0.000	0.008	0.000	0.000
46	5.237	0.009	0.023	0.000	0.000
47	5.724	0.006	0.011	0.000	0.000

	AE	AF	AG
1	C	F/M	F/FM
2			
3	22.000	0.114	0.103
4	22.000	0.112	0.101
5	22.000	0.115	0.103
6	22.000	0.092	0.085
7	22.000	0.080	0.074
8	22.000	0.035	0.034
9	22.000	0.069	0.064
10	22.000	0.070	0.065
11	22.000	0.070	0.065
12	22.000	0.070	0.065
13	22.000	0.068	0.063
14	22.000	0.065	0.061
15	22.000	0.100	0.091
16	22.000	0.026	0.025
17	22.000	0.025	0.024
18	22.000	0.124	0.110
19	22.000	0.062	0.058
20	22.000	0.056	0.053
21	22.000	0.048	0.046
22	22.000	0.045	0.043
23	22.000	0.044	0.042
24	22.000	0.055	0.052
25	22.000	0.039	0.038
26	22.000	0.071	0.066
27	22.000	0.066	0.062
28	22.000	0.040	0.038
29	22.000	0.041	0.040
30	22.000	0.039	0.038
31	22.000	0.044	0.042
32	22.000	0.072	0.067
33	22.000	0.017	0.017
34	22.000	0.021	0.020
35	22.000	0.190	0.190
36	22.000	0.103	0.930
37	22.000	0.056	0.053
38	22.000	0.126	0.112
39	22.000	0.042	0.040
40	22.000	0.072	0.067
41	22.000	0.017	0.017
42	22.000	0.021	0.020
43	22.000	0.019	0.019
44	22.000	0.103	0.093
45	22.000	0.056	0.053
46	22.000	0.126	0.112
47	22.000	0.042	0.040

APPENDIX E-5: SERPENTINE

	A	B	C	D	E
1	SAMPLE #	GRAIN #	ROCK TYPE	TRAVERSE	DISTANCE
2					
3	RISO-51	1	P	3	0
4	RISO-51	2	P	3	0
5	RISO-46	1	P	3	260
6	RISO-46	2	P	3	260
7	RISO-46	3	P	3	260
8	RISO-46	4	P	3	260
9	RS-16-849	1	P	2	28
10	RISO-51	3	P	3	0
11	RISO-51	4	P	3	0
12	RISO-51	5	P	3	0

	F	G	H	I	J
1	MODE	Si02	Ti02	Al203	Cr203
2					
3	M	42.10	0.00	0.91	0.60
4	M	37.07	0.00	0.21	0.13
5	M	41.61	0.04	1.17	0.16
6	M	39.32	0.09	4.53	0.39
7	M	39.69	0.06	4.49	0.35
8	M	39.25	0.08	0.63	0.07
9	M	43.25	0.00	0.27	0.03
10	M	40.88	0.00	0.88	0.02
11	M	42.40	0.00	0.75	0.07
12	M	42.80	0.00	0.77	0.00

	K	L	M	N	O
1	Fe0	Mn0	Mg0	Ca0	Ba0
2					
3	6.60	0.00	36.04	0.07	0.04
4	6.23	0.00	37.25	0.05	0.05
5	4.64	0.06	36.16	0.03	0.02
6	5.13	0.02	36.06	0.05	0.00
7	4.61	0.00	35.81	0.06	0.04
8	3.96	0.00	37.45	0.01	0.00
9	7.16	0.00	35.80	0.00	0.00
10	6.80	0.00	34.44	0.00	0.00
11	7.04	0.00	35.58	0.00	0.00
12	6.94	0.00	34.57	0.00	0.00

	P	Q	R
1	Na20	K20	SUM
2			
3	0.00	0.03	86.40
4	0.00	0.03	81.02
5	0.00	0.01	83.92
6	0.00	0.00	85.61
7	0.00	0.00	85.10
8	0.00	0.00	81.46
9	0.00	0.00	86.61
10	0.00	0.00	83.02
11	0.00	0.00	85.85
12	0 21	0.00	85.29

APPENDIX E-6: CHROMITE

	A	B	C	D	E
1	SAMPLE #	GRAIN #	ROCK TYPE	TRAVERSE	DISTANCE
2					
3	RISO-50	1	T	3	50
4	RISO-50	2	T	3	50
5	RISO-50	3	T	3	50
6	RISO-49	1	B	3	72
7	RISO-51	1	P	3	0
8	RS-26-191	1	T	1	55
9	RS-26-191	2	T	1	55
10	RS-26-191	3	T	1	55
11	RISO-46	1	P	3	260
12	RISO-46	2	P	3	260
13	RS-26-259	1	P	1	101
14	RS-26-259	2	P	1	101
15	RS-16-849	1	P	2	28
16	RS-16-482	1	P	2	212

	F	G	H	I	J
1	MODE	Si02	Ti02	Al203	Cr203
2					
3	F	1.78	0.95	13.30	41.59
4	F	1.23	0.66	13.39	43.35
5	F	1.72	0.74	10.95	44.49
6	F	4.88	0.45	9.75	43.52
7	M	1.45	0.32	20.50	43.82
8	M	1.46	0.76	13.37	44.54
9	M	1.11	0.53	15.97	41.65
10	M	1.69	0.57	16.96	38.72
11	M	1.30	0.53	10.09	41.49
12	M	1.57	0.34	2.94	39.18
13	M	0.91	0.33	20.77	43.35
14	M	0.97	0.42	17.63	45.54
15	M	1.65	0.46	12.67	35.42
16	M	1.04	0.55	15.66	50.13

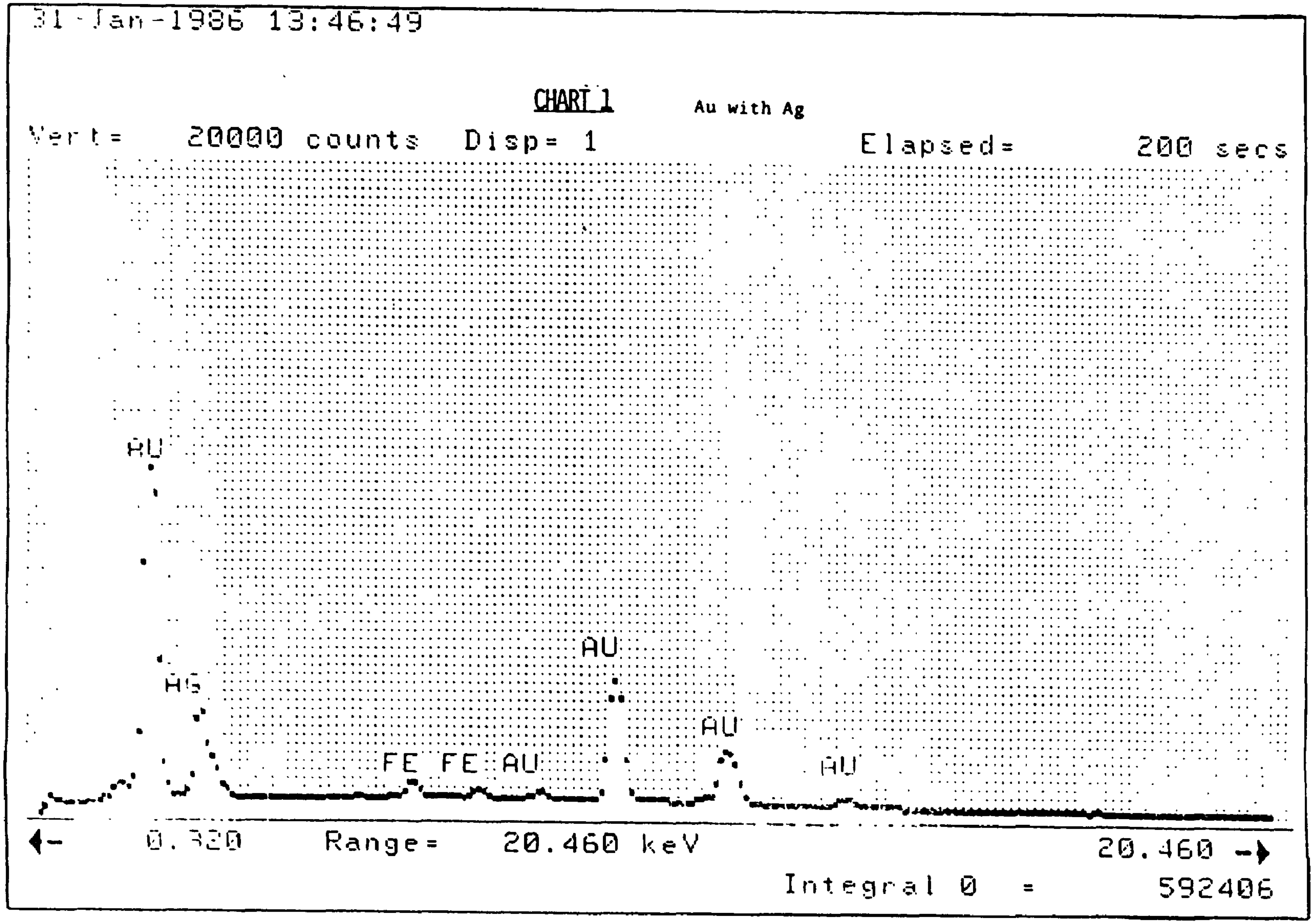
	K	L	M	N	O
1	FeO	MnO	MgO	CaO	BaO
2					
3	40.97	1.46	0.13	0.13	0.52
4	39.61	1.38	0.15	0.15	0.45
5	38.66	1.60	0.09	0.09	0.47
6	32.53	0.93	0.12	0.12	0.40
7	25.69	0.98	0.18	0.18	0.32
8	36.29	1.05	0.01	0.01	0.39
9	37.05	1.13	0.00	0.00	0.31
10	39.27	0.82	0.39	0.39	0.44
11	43.23	1.01	0.13	0.13	0.38
12	51.67	1.00	0.13	0.13	0.43
13	28.98	0.98	0.10	0.10	0.33
14	30.02	0.96	0.11	0.11	0.35
15	44.14	0.70	0.14	0.14	0.29
16	31.95	0.93	0.14	0.14	0.28

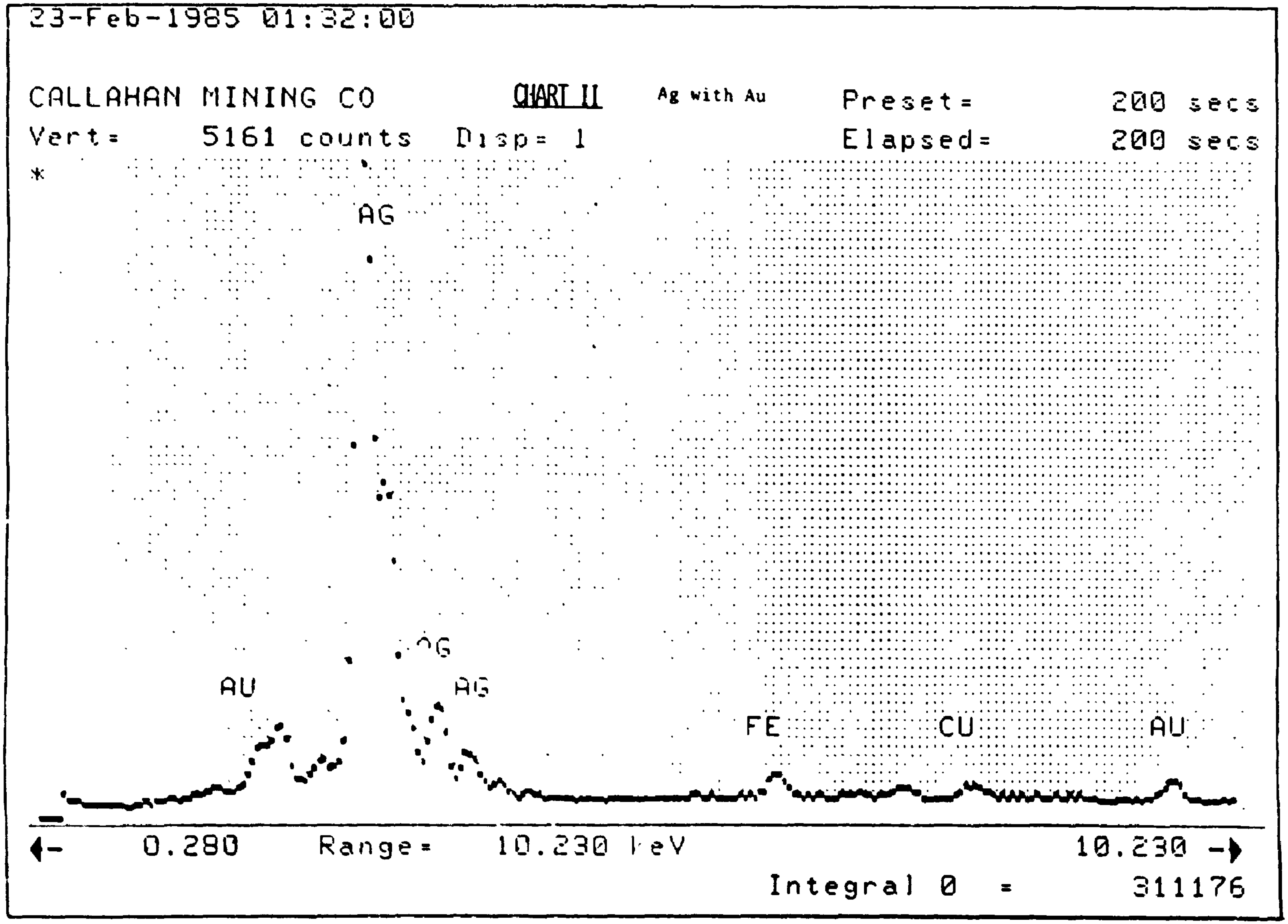
	P	Q	R
1	Na20	K20	SUM
2			
3	0.00	0.08	101.37
4	0.14	0.09	101.25
5	0.03	0.11	99.53
6	0.11	0.10	99.39
7	0.00	0.13	100.67
8	0.09	0.05	101.64
9	0.13	0.07	101.95
10	0.26	0.06	100.11
11	0.00	0.07	99.16
12	0.00	0.06	98.21
13	0.00	0.05	99.77
14	0.00	0.07	98.56
15	0.07	0.05	102.42
16	0.31	0.02	103.65

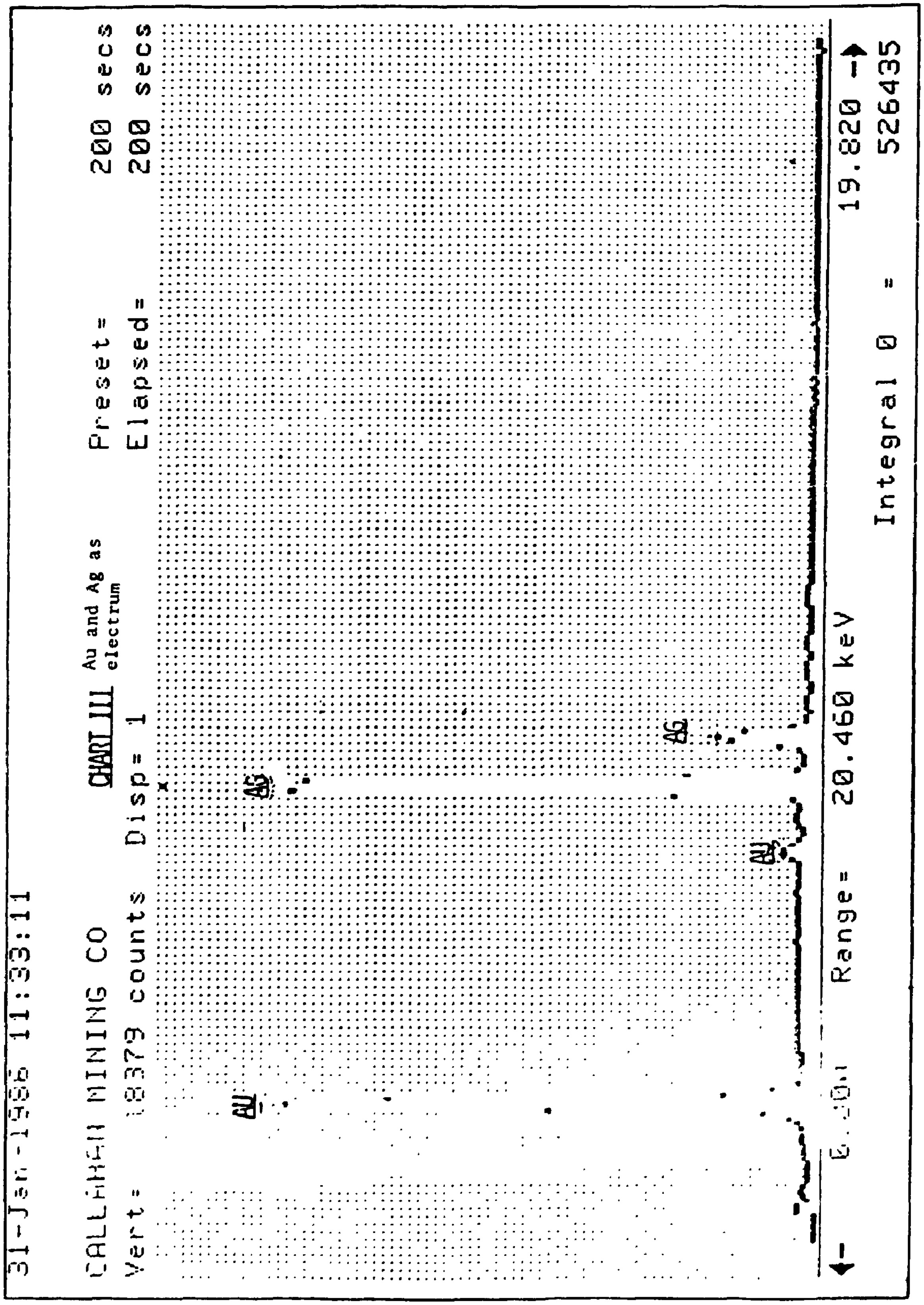
APPENDIX F

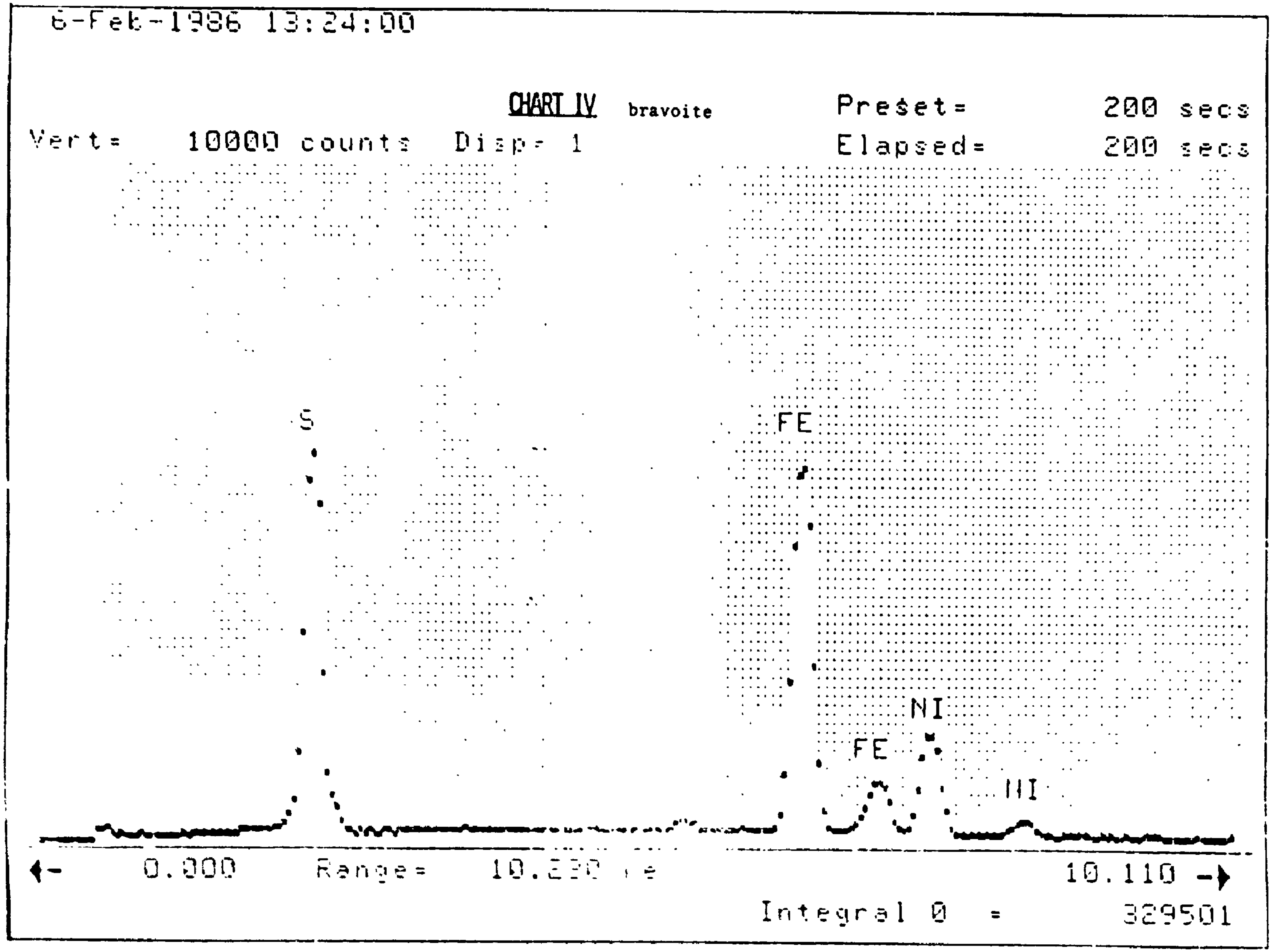
QUALITATIVE ENERGY DISPERSIVE SPECTRA FOR METALLIC MINERALS FROM ROPES DEPOSIT

(Charts I to V from Rorick, 1986)
(Charts VI to IX this study)


31-Jan-1986 13:46:49
CHART 1
Au with Ag
Vert= 20000 counts Disp= 1
Elapsed= 200 secs
AU
AG
FE FE AU
AU
AU
AU
0.320
Range= 20.460 keV
20.460
Integral 0 = 592406


23-Feb-1985 01:32:00
CALLAHAN MINING CO
CHART II
Ag with Au
Preset= 200 secs
Vert= 5161 counts
Disp= 1
Elapsed= 200 secs
*
AG
AG
AU
AG
FE
CU
AU
0.280
Range= 10.230 keV
10.230
Integral 0 = 311176


31-Jan-1986 11:33:11
CALLAHAN MINING CO
CHART III
Au and Ag as electrum
Preset= 200 secs
Vert= 18379 counts
Disp= 1
Elapsed= 200 secs
AU
AG
AU
AG
Range= 20.460 keV
19.820
Integral 0 = 526435


6-Feb-1986 13:24:00
CHART IV bravoite
Preset= 200 secs
Vert= 10000 counts Disp= 1
Elapsed= 200 secs
S
FE
NI
FE
NI
0.000
Range= 10.230
10.110
Integral 0 = 329501

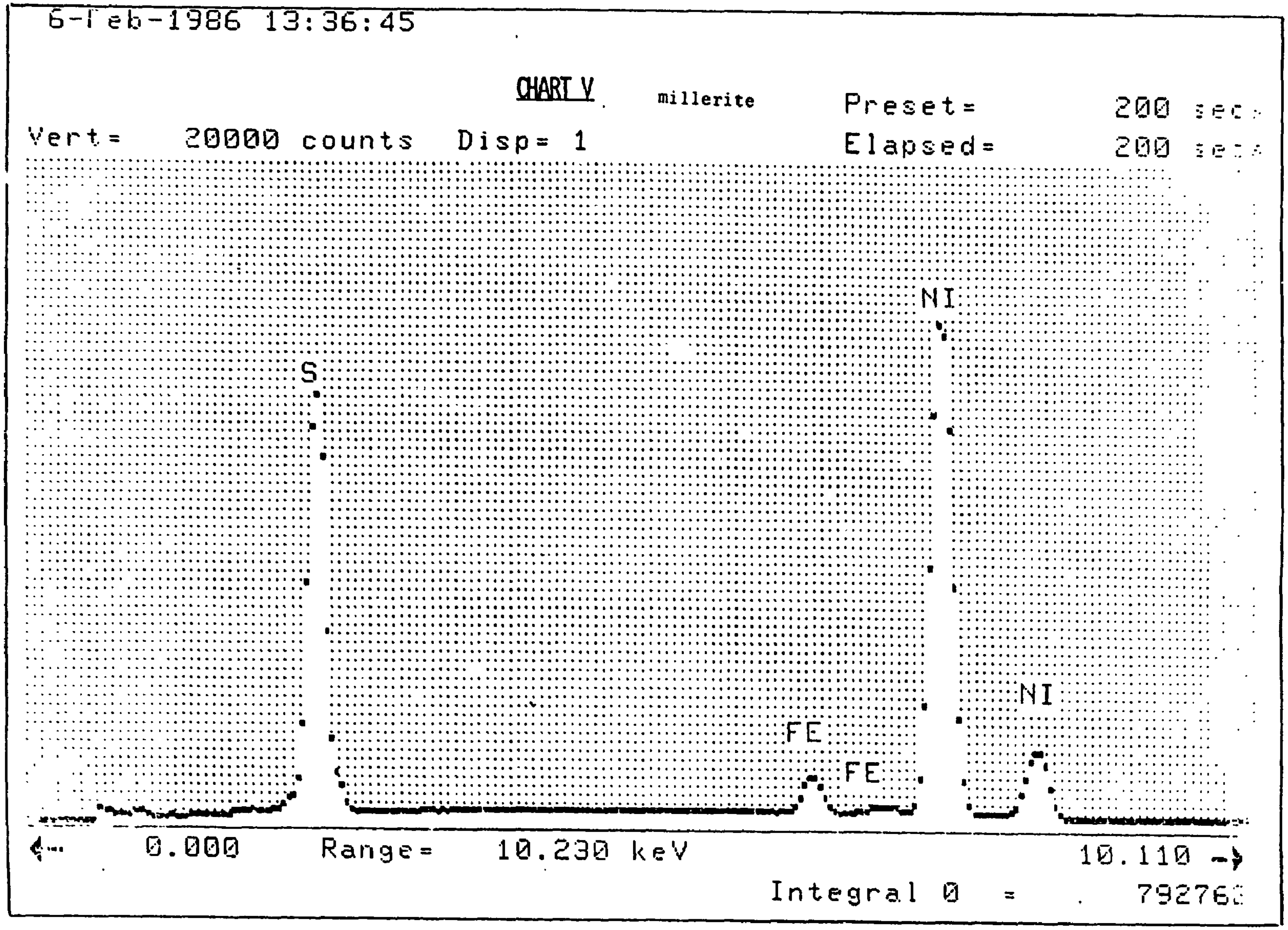
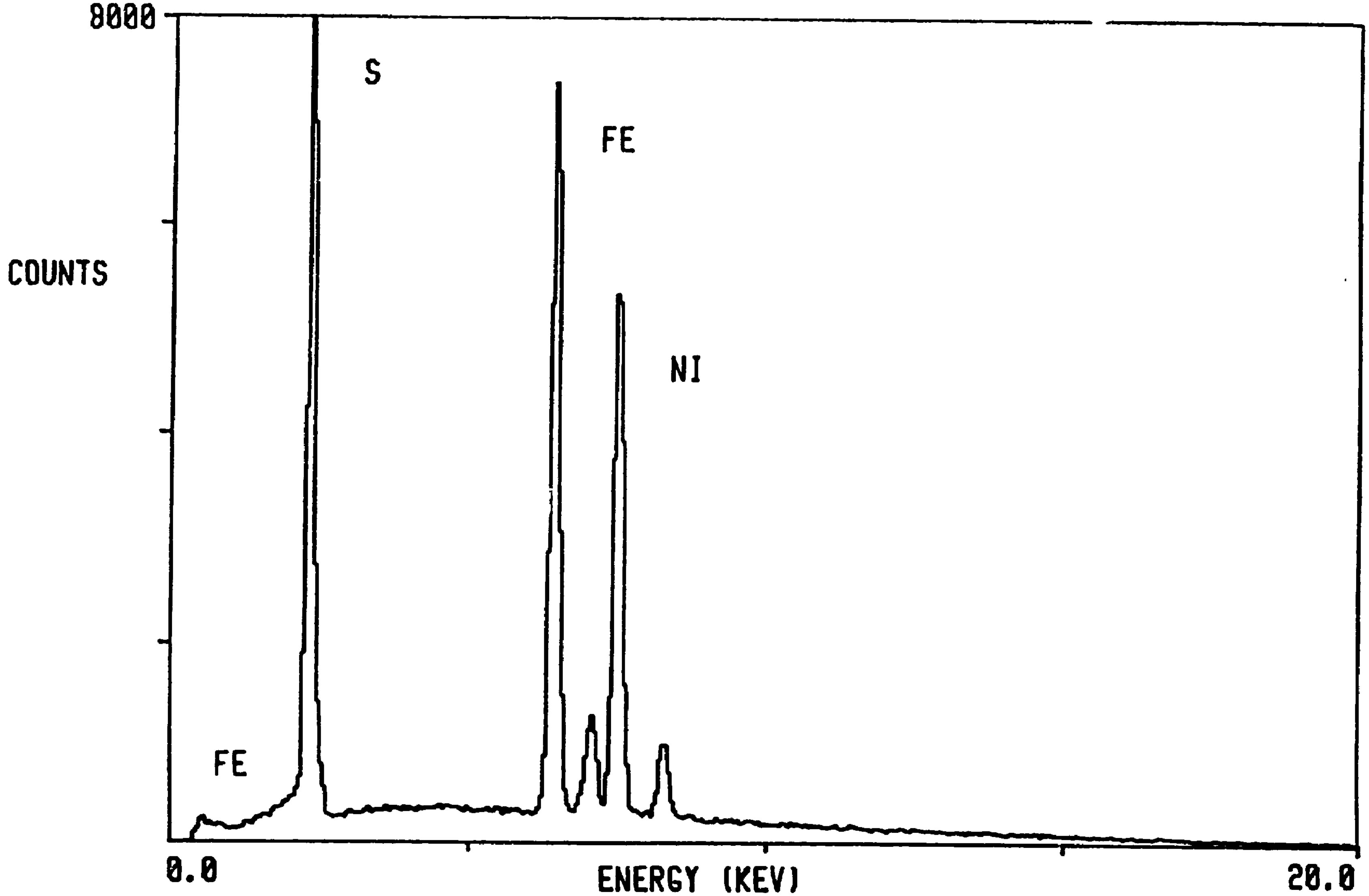
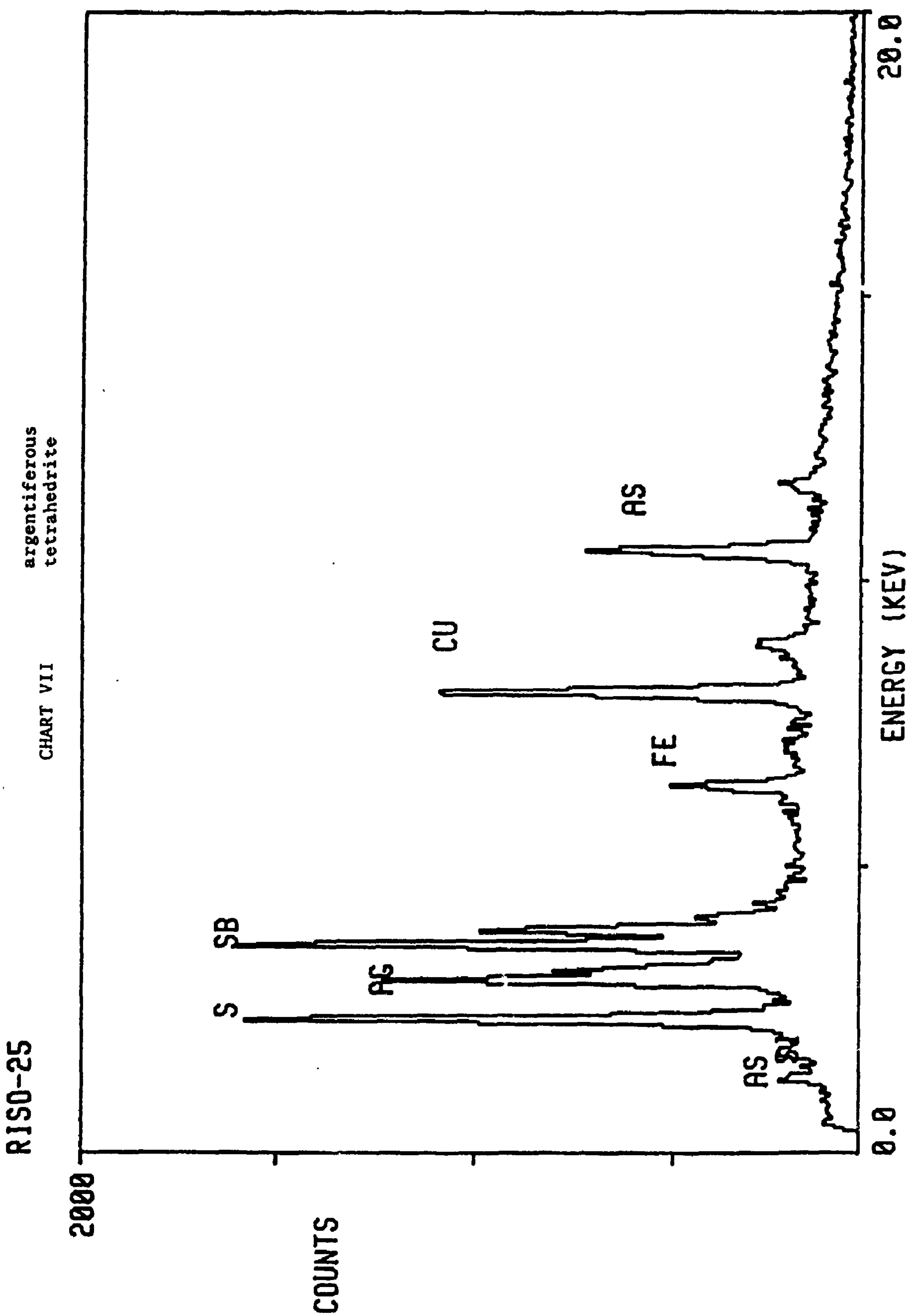
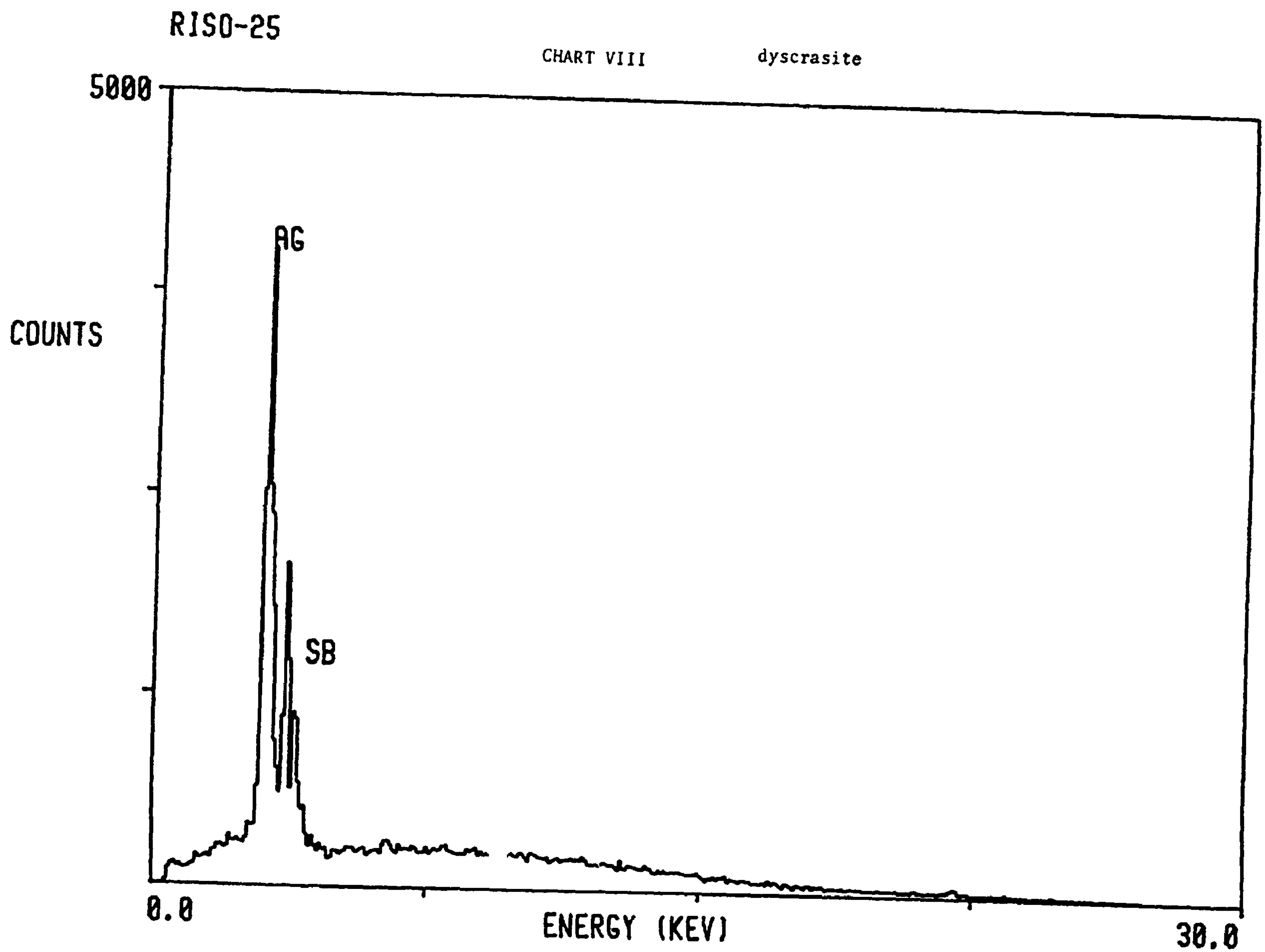

6-Feb-1986 13:36:45
CHART V
millerite
Preset= 200 sec
Vert= 20000 counts Disp= 1
Elapsed= 200 sec
S
NI
FE
FE
NI
0.000 Range= 10.230 keV
10.110
Integral 0 = 79276

CHART VI millerite

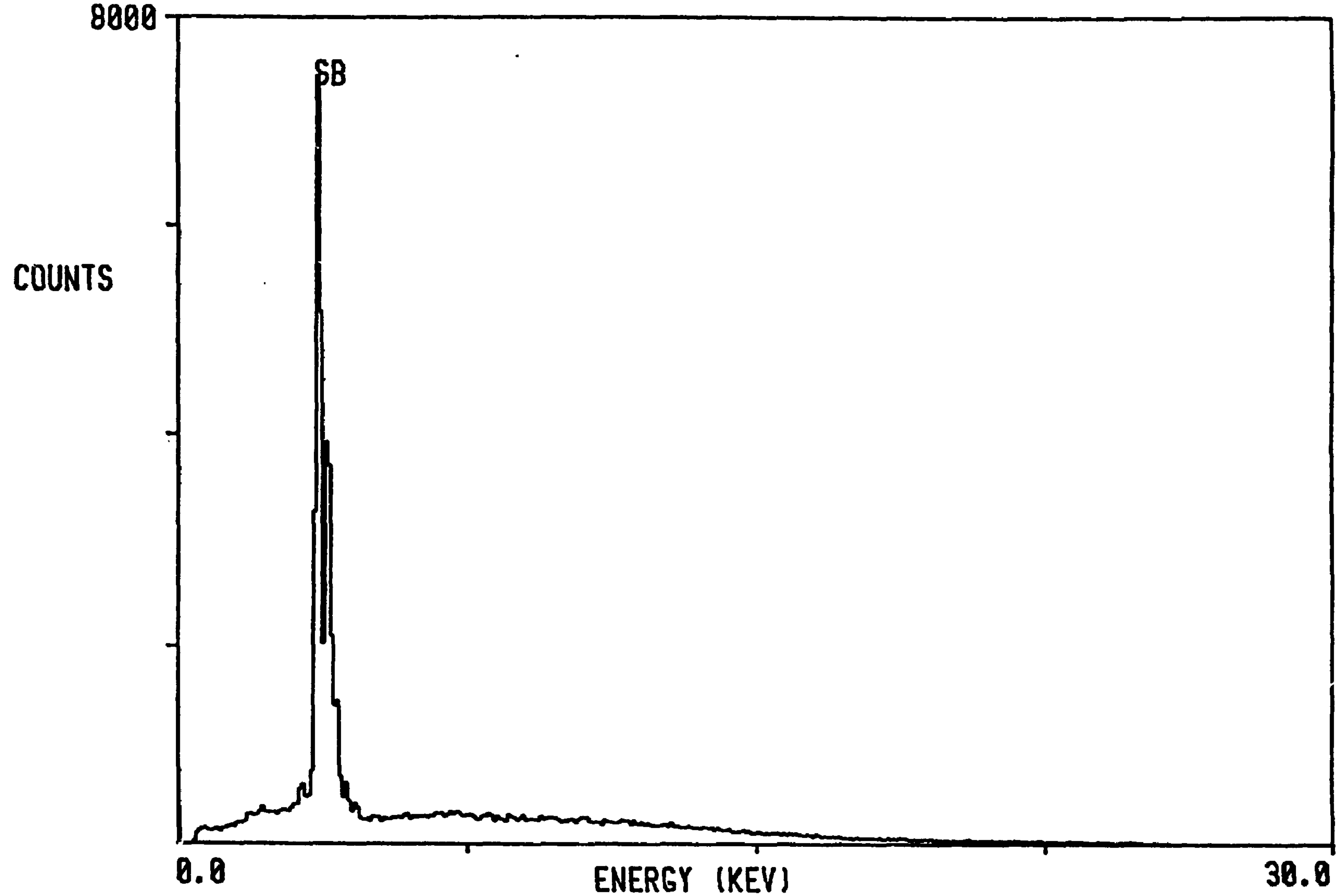


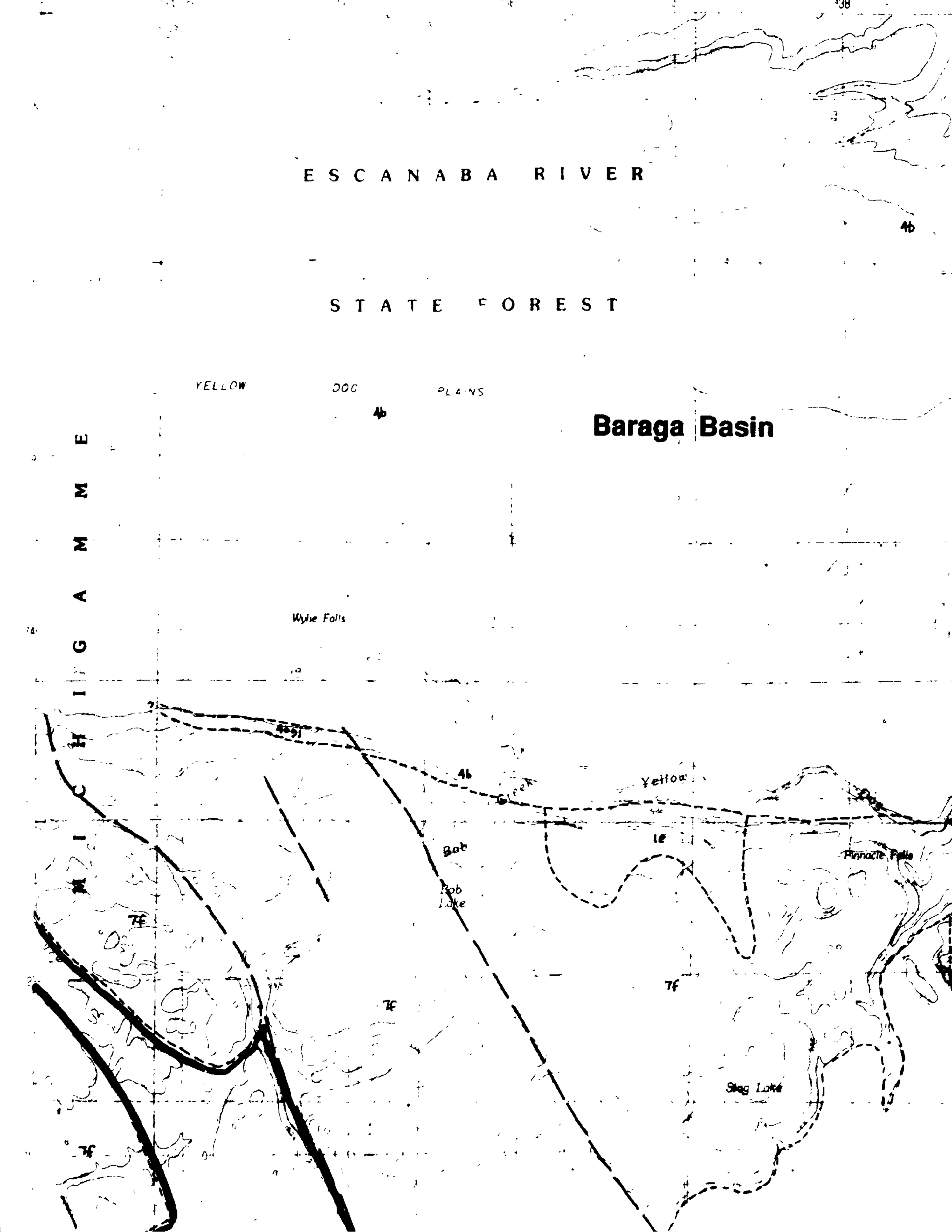

RISO-25
CHART VII
argentiferous
tetrahedrite
COUNTS
2000
0.0
20.0
ENERGY (KEV)
S
SB
AG
AS
FE
CU
AS


RISO-25
CHART VIII
dyscrasite
5000
COUNTS
AG
SB
0.0
ENERGY (KEV)
30.0

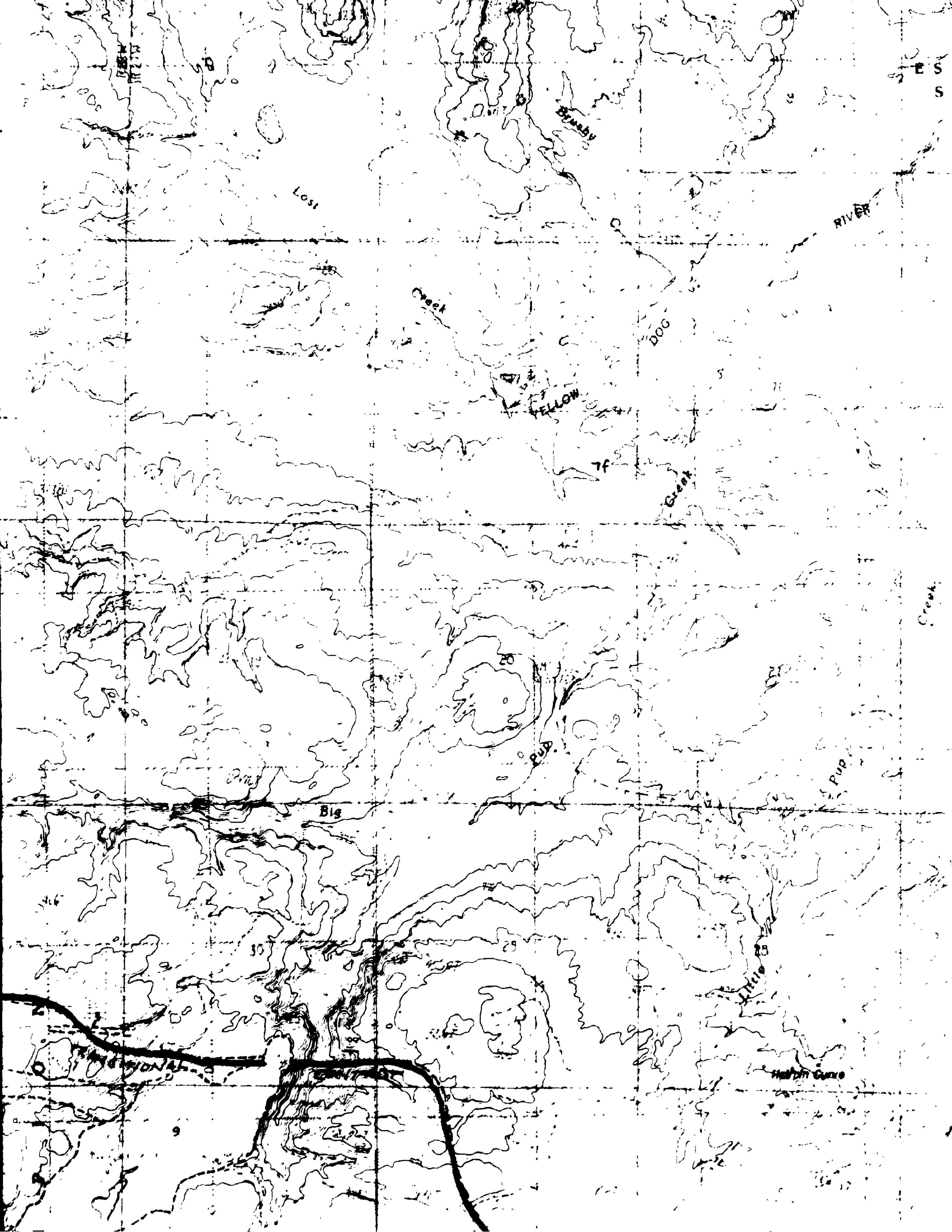
RISO-25

CHART IX native antimony

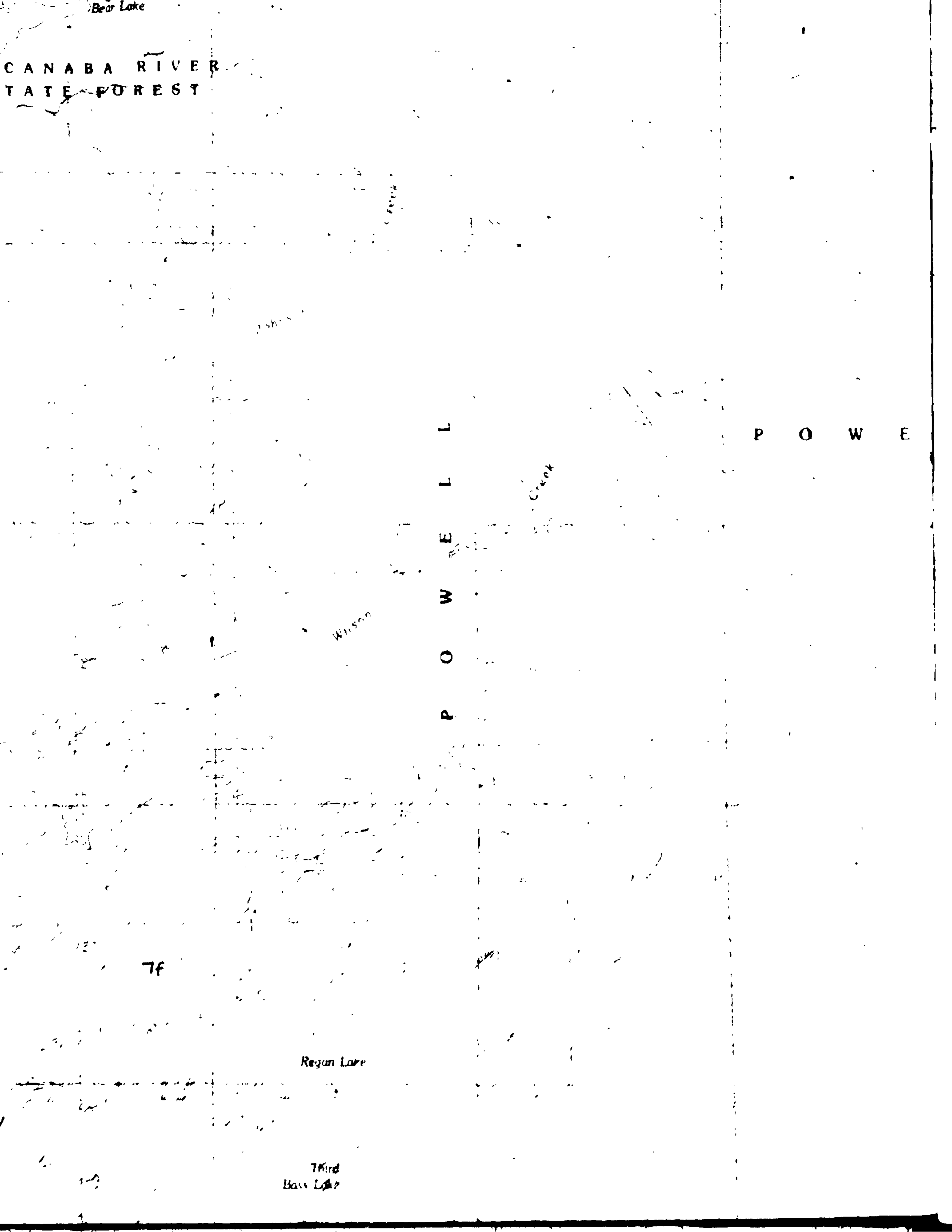


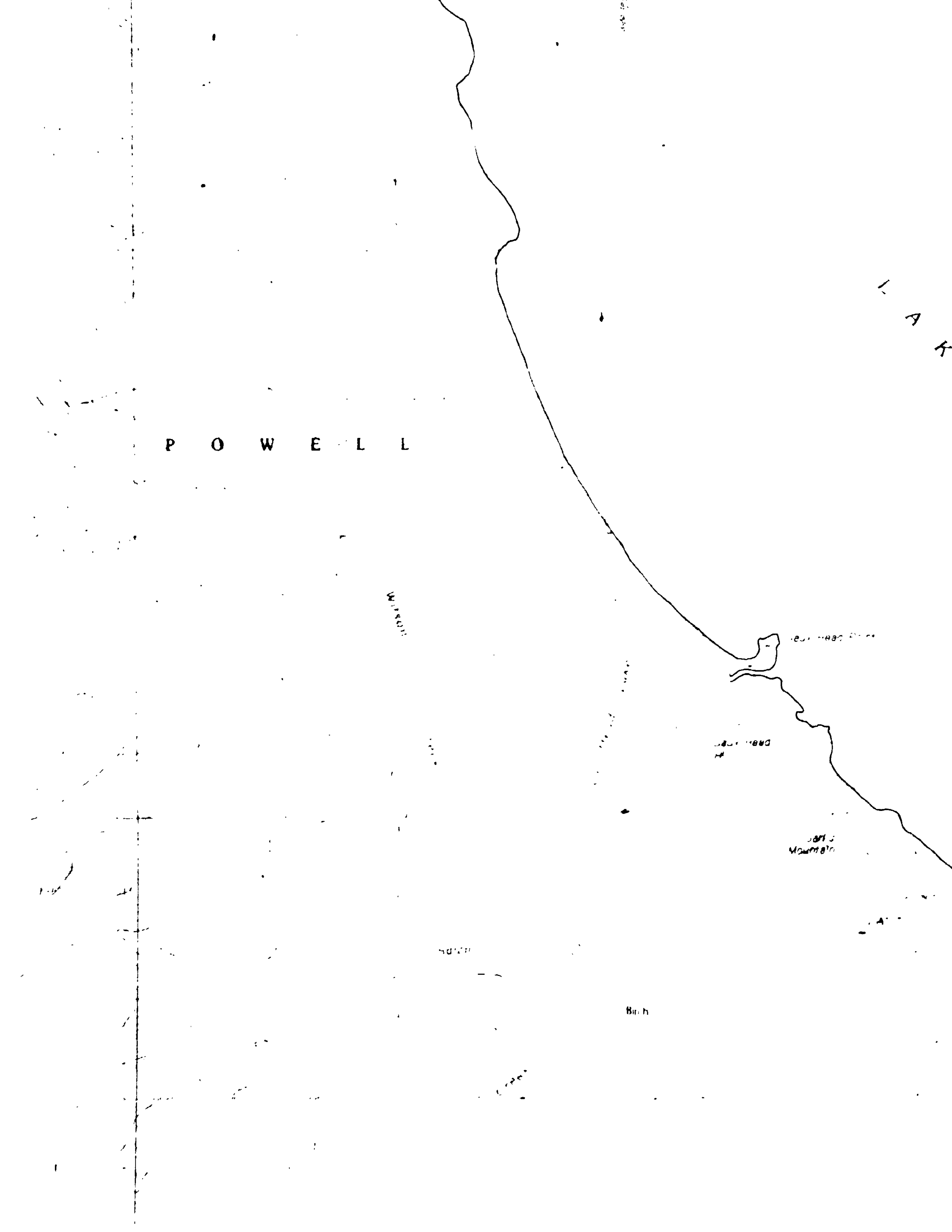

ESCANABA RIVER
STATE FOREST
YELLOW DOG PLAINS
4b
Baraga Basin
MICHIGAMME
Wylie Falls
Yellow
Bob Lake
Pinnacle Falls
7f
Stag Lake

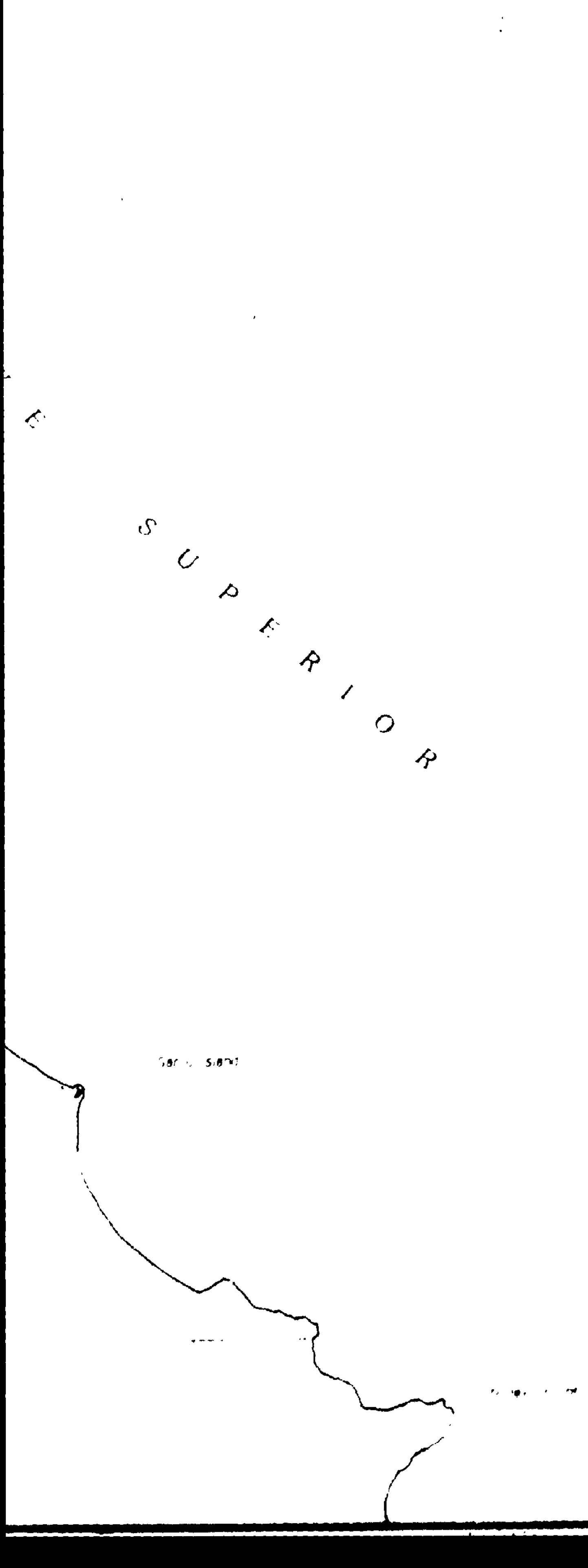
Lost Creek
INFERRED FROM DRILLING AND AEROMAG DATA
Pup Cr
TRANSITIONAL



Lost
Creek
Brushy
RIVER
DOG
YELLOW
Creek
Creek
20
Pup
Pup
Big
30
29
25
Little
9
Halfpin Curve


Bear Lake
CANABA RIVER
TATE FOREST
POWELL
POWE
Creek
Wilson
Regan Lake
Third
Bass Lake


P O W E L L



EXPLANATION

ROCK TYPES:

11. veins
    q - quartz
    c - carbonate
10. talus
9. glacial till or outwash
8. Keweenawan dike
7. gneiss
    f - felsic
    m - mafic
6. intra - greenstone belt intru
    a. granite
    b. granodiorite
    c. tonalite
    d. quartz monzonite
    e. syenite
    f. diorite
    g. feldspar porphyritic sy
5. peridotite and related rocks
    a. serpentinitic peridotit
        c - carbonate rich
        t - carbonate - talc r
        d - carbonate - quartz
4. sedimentary rocks
    a. conglomerate
    b. graywacke
    c. siltstone
    d. slate
    e. volcaniclastic sediment
        f - felsic provenance
        m - mafic provenance
    f. carbonaceous slate
    g. quartzite
    h. dolomite and silty dol
    i. sandstone
    j. arkose
3. chemical sedimentary rocks
    a. iron formation
        o - oxide facies
        p - sulfide facies
        s - silicate facie
        c - carbonate facies
    b. chert
    c. chert with clastic com
2. dacite and rhyodacite volca
    a. flow/dome
        p - porphyritic
    b. tuff
        p - feldspar or quart
        t - tuff breccia
        l - lapilli tuff
        m - sericite rich
        s - siliceous, common
    c. hypabyssal sill/dike
        p - porphyritic

EXPLANATION

Map Pl

..K TYPES:

1. veins
   - q - quartz
   - c - carbonate
0. talus
9. glacial till or outwash
8. Keweenawan dike
7. gneiss
   - f - felsic
   - m - mafic
6. intra - greenstone belt intrusive rocks
   - a. granite
   - b. granodiorite
   - c. tonalite
   - d. quartz monzonite
   - e. syenite
   - f. diorite
   - g. feldspar porphyritic syenite
5. peridotite and related rocks
   - a. serpentinitic peridotite
     - c - carbonate rich
     - t - carbonate - talc rock
     - d - carbonate - quartz - chlorite rock
. sedimentary rocks
   - a. conglomerate
   - b. graywacke
   - c. siltstone
   - d. slate
   - e. volcaniclastic sedimentary rocks
     - f - felsic provenance
     - m - mafic provenance
   - f. carbonaceous slate
   - g. quartzite
   - h. dolomite and silty dolomite
   - i. sandstone
   - j. arkose
3. chemical sedimentary rocks
   - a. iron formation
     - o - oxide facies
     - p - sulfide facies
     - s - silicate facies
     - c - carbonate facies
   - b. chert
   - c. chert with clastic component
. dacite and rhyodacite volcanic rocks, with rhyolite sills (1.5 andesite)
   - a. flow/dome
     - p - porphyritic
   - b. tuff
     - p - feldspar or quartz crystal rich
     - f - tuff breccia
     - l - lapilli tuff
     - m - sericite rich
     - s - siliceous, commonly with abundant quartz veins
   - c. hypabyssal sill/dike (mostly rhyolite)
     - p - porphyritic

1. basalt
   - a. flow
     - p - pillowed
     - v - variolitic
     - o - ophitic
     - f - flow top breccia
     - g - glomerophyric
     - c - carbonate rich
     - m - sericite rich
   - b. tuff
     - f - tuff breccia
     - l - lapilli tuff
     - c - carbonate rich
     - m - sericite rich
   - c. gabbro sills, probably co-magmatic with basalts
   - d. diabase dike/sill
   - e. layered amphibolite
     - s - felsic schlieren

Outline of Marquette greenstone belt

Rock type number codes also apply to rocks greenstone belt, which are mostly Lower Proteroz Archean gneisses

Geologic contact

Shear zone

U D Fault, with sense of offset if known

80 Strike and dip of foliation

50 Strike and dip of bedding

30 Strike and dip of joint

80 Bearing and plunge of lineation

Younging directon

pillowed basalt

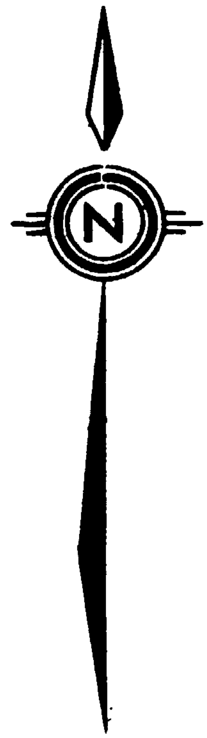
bedding

Shaft

..in r prospect

te *1a. Geologic Map of the Marquette Greenstone Belt

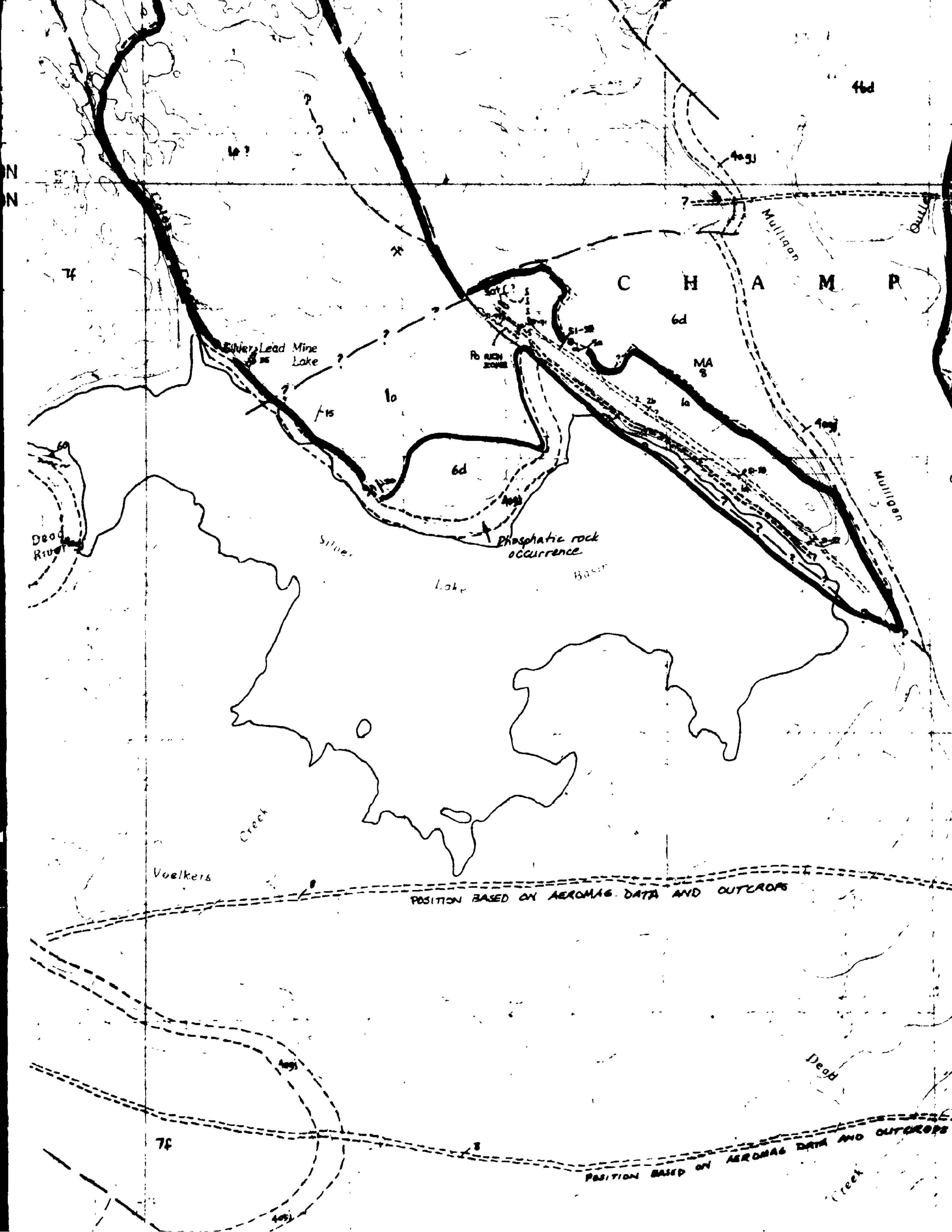
. bordering the Marquette
oic sedimentary rocks and



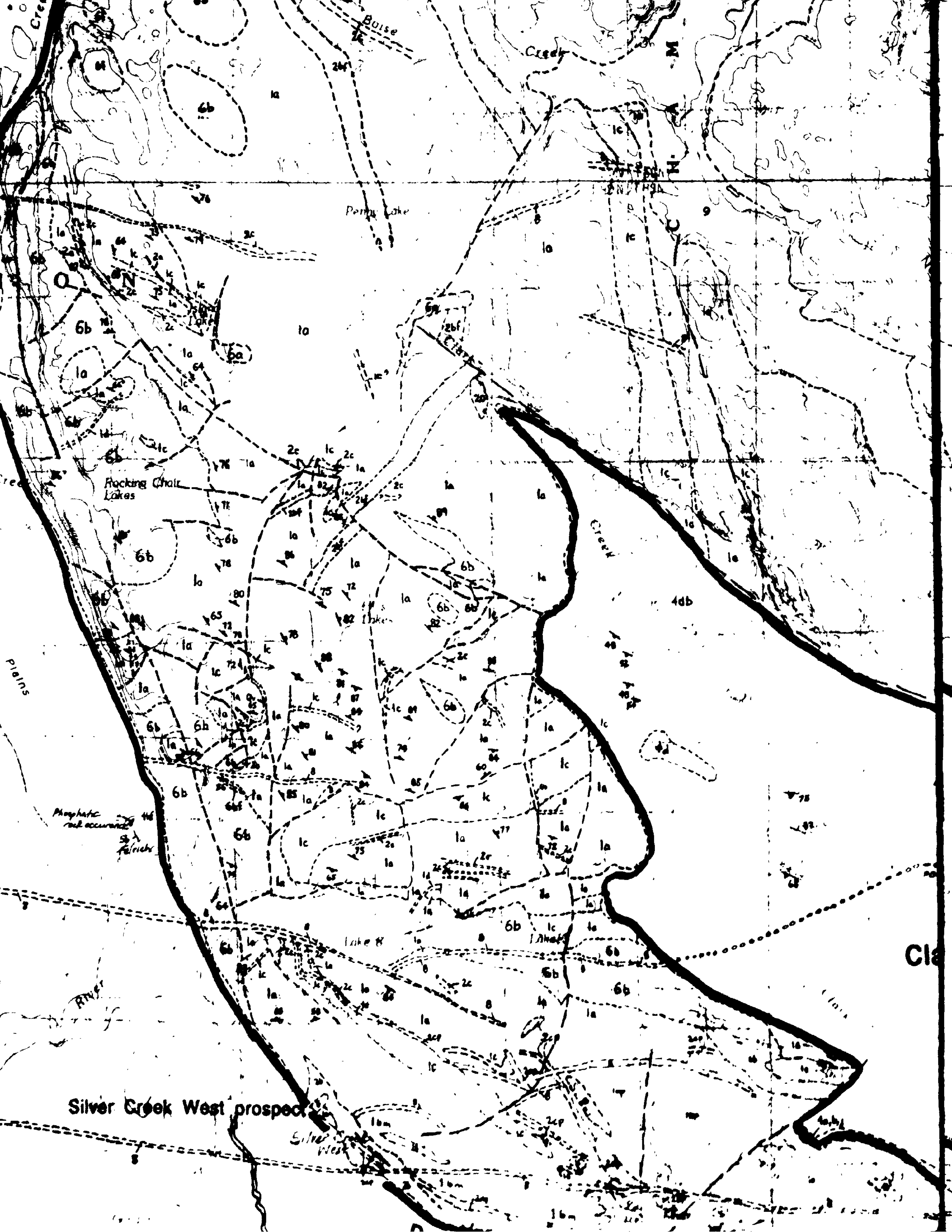
Scale

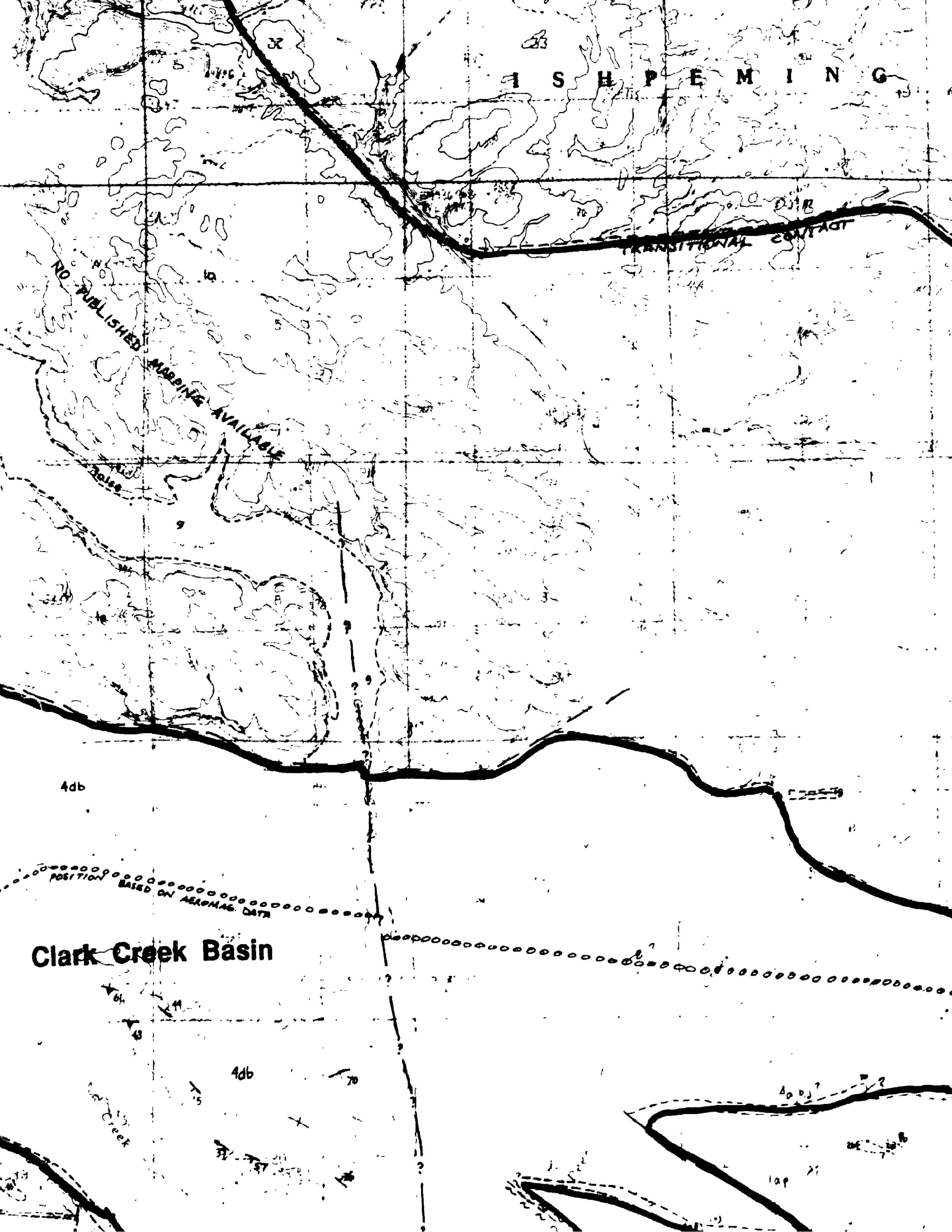
0 ft. 2000

0 m 610

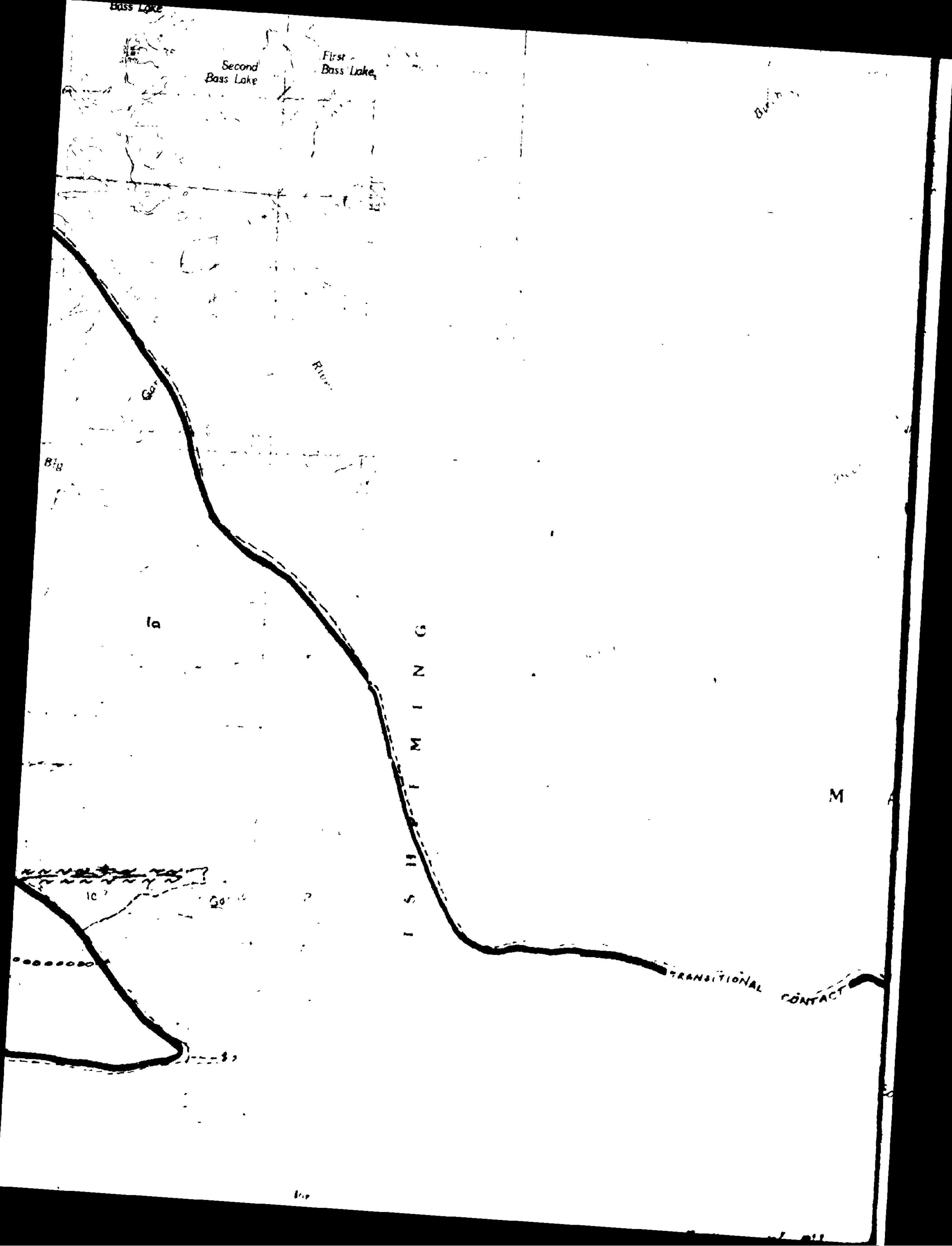


C H A M P
4bd
4agj
Mulligan
6d
MA
8
1a
Silver Lead Mine
Lake
Pb RICH ZONE
Phosphatic rock
occurrence
Silver
Lake
Basin
Dead
River
7f
Creek
Voelkers
POSITION BASED ON AEROMAG DATA AND OUTCROPS
Dead
Creek

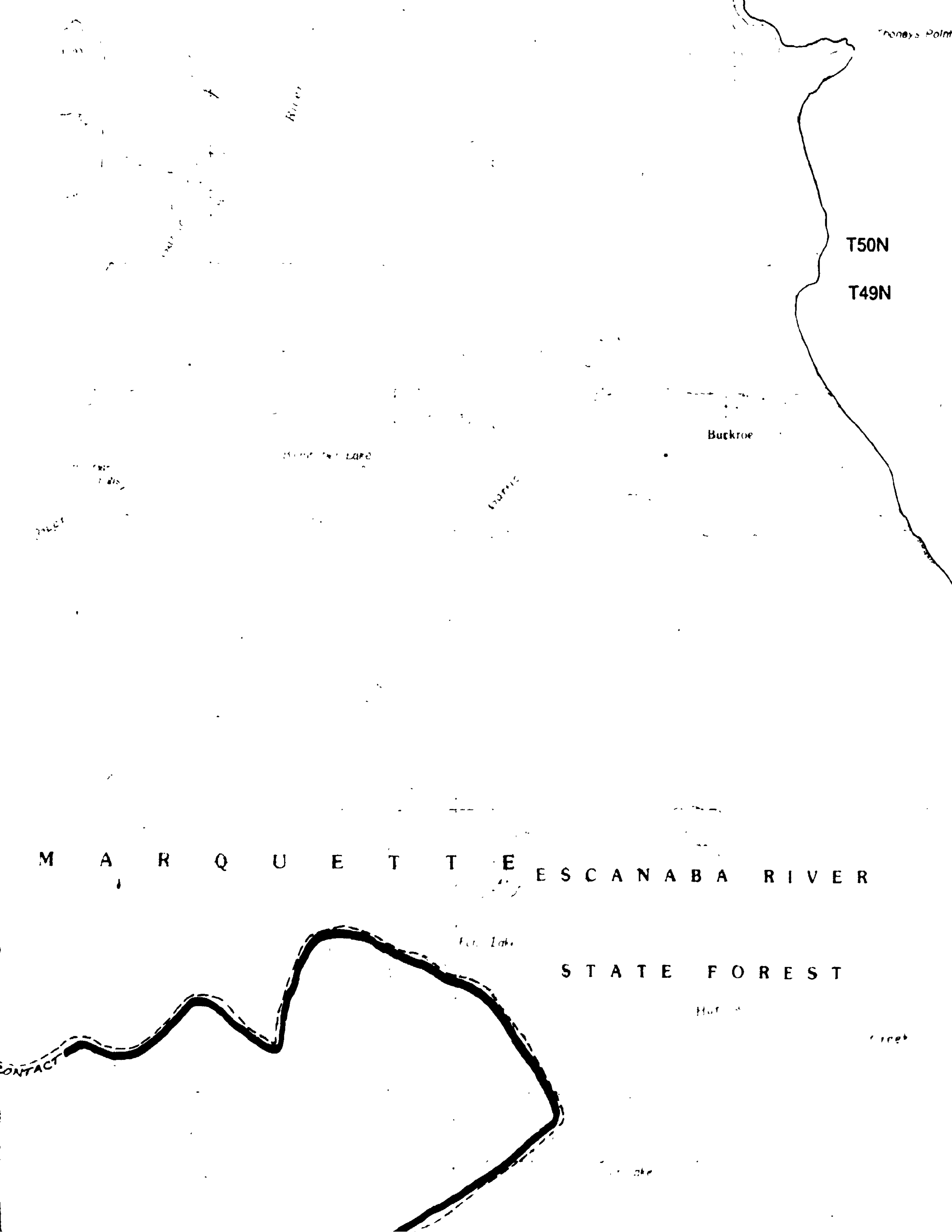

Boise
Creek
Penny Lake
Rocking Chair Lakes
Plains
Phosphatic rock occurrence
Lake 8
Cla
Silver Creek West prospect
River

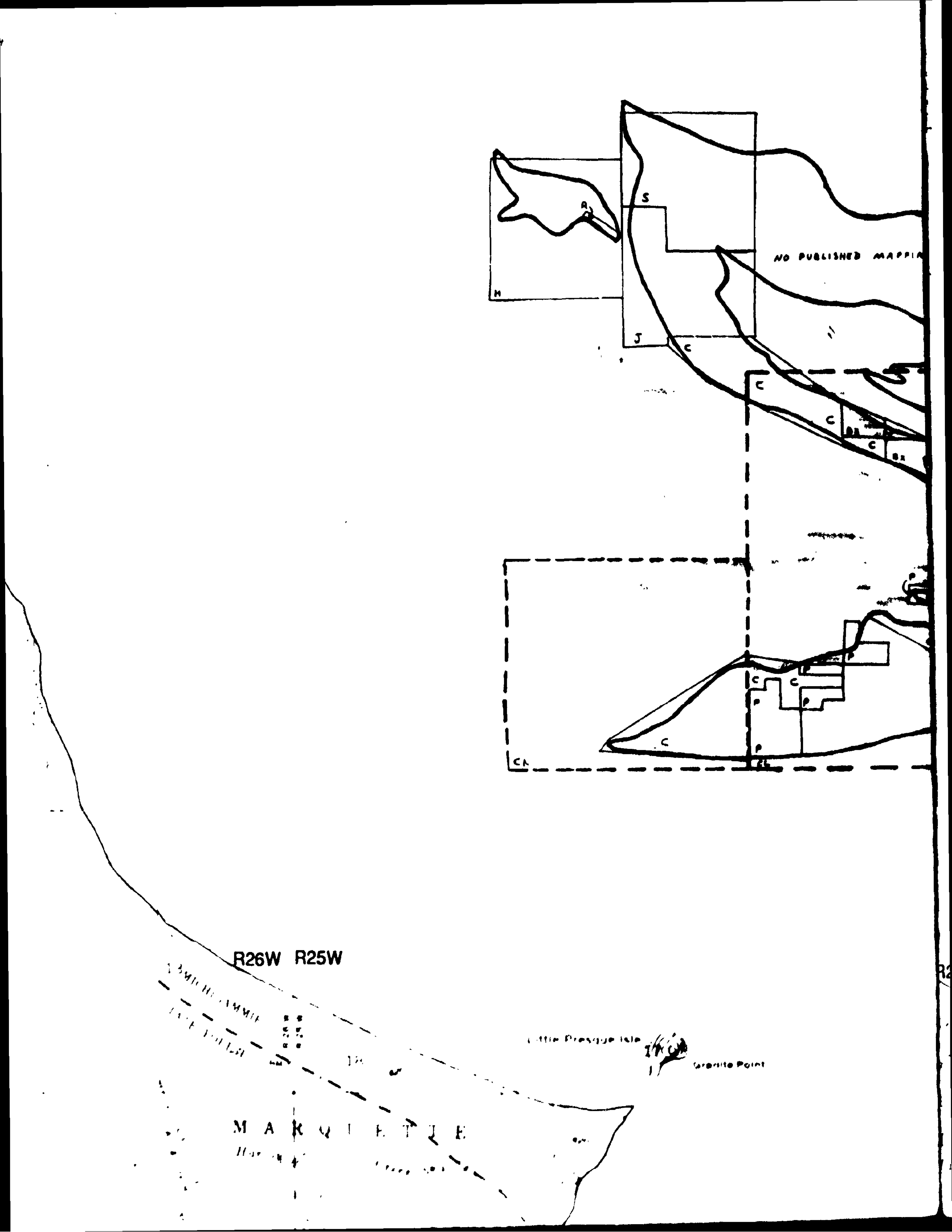


I S H P E M I N G
TRANSITIONAL CONTACT
NO PUBLISHED MAPPING AVAILABLE
4db
POSITION BASED ON AEROMAG DATA
Clark Creek Basin
4db

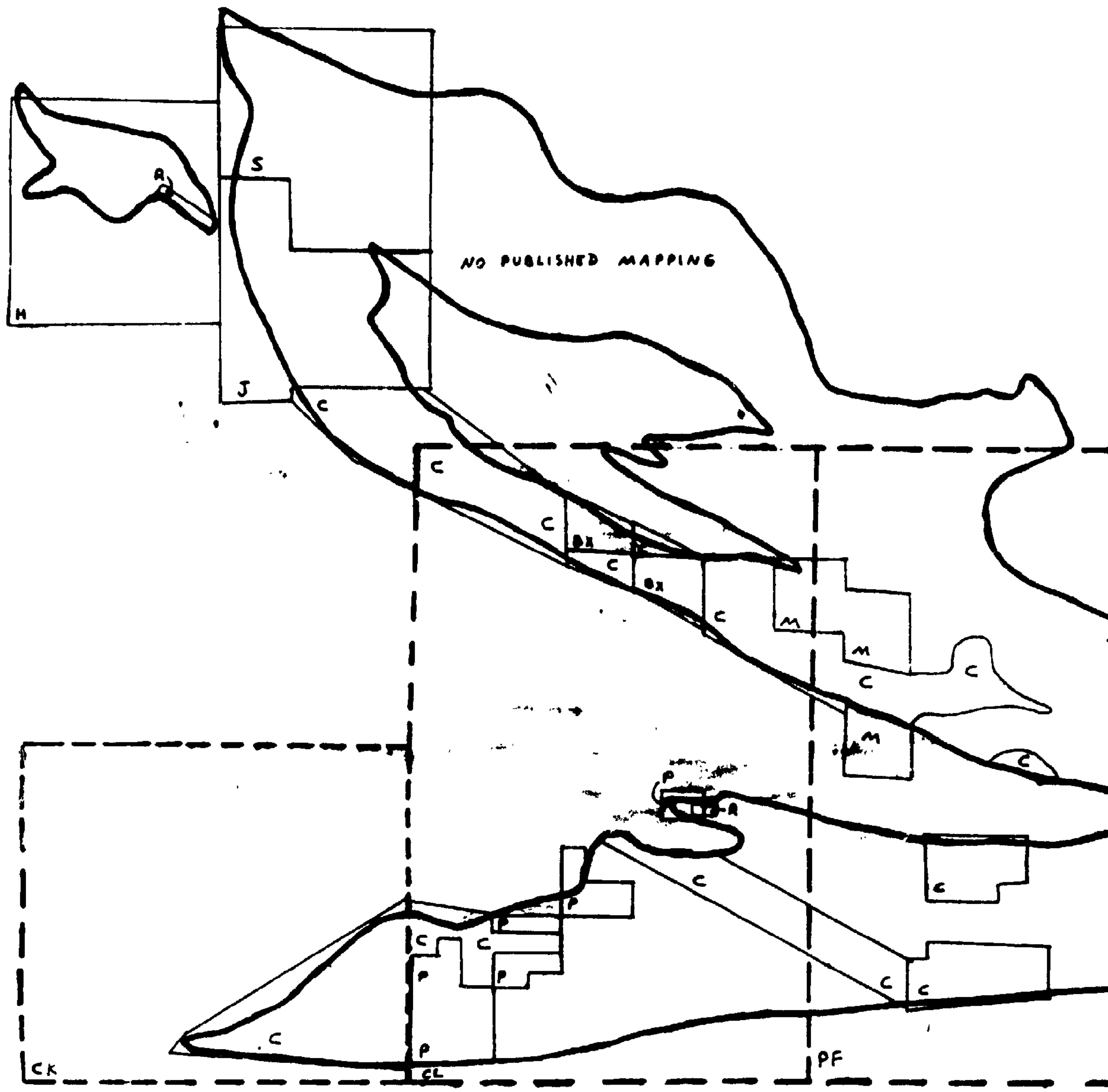


Bass Lake
Second Bass Lake
First Bass Lake
Ia
TRANSITIONAL CONTACT
M


T50N
T49N
Buckroe
MARQUETTE
ESCANABA RIVER
STATE FOREST


NO PUBLISHED MAPPIN
R26W R25W
Little Presque Isle
Granite Point
M A R Q U E T T E

p - porphyritic



Callahan Mining Cor

Key to sources of i

Internal Company Re

C = Callahan M
(A. S. Ca
G. B. Mar
R. W. Hod

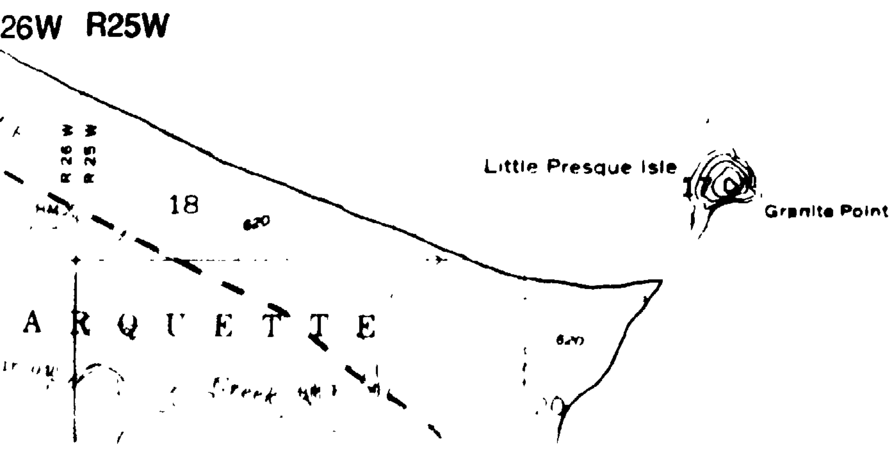
P = Phelps Dod

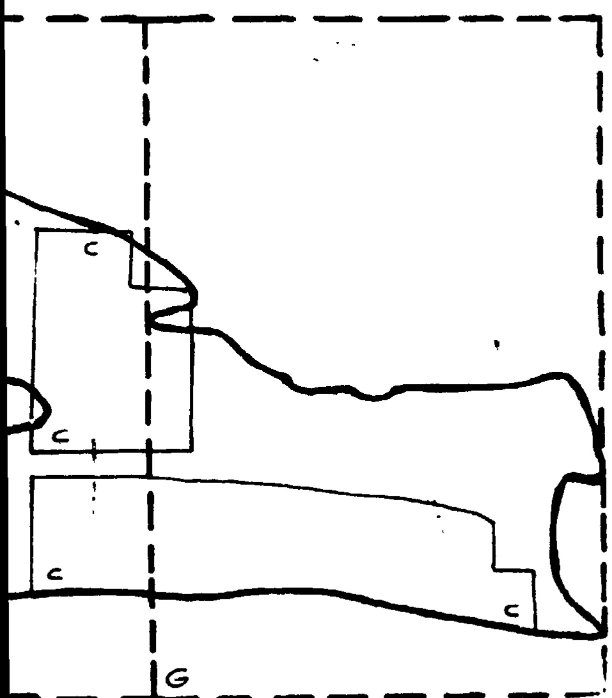
R = Resource E

H = Humble Oil

Michigan Geologica
Technological Uni
Technological Unive

(Only mapped
used in this c





rporation Geologic Compilation

information:

eports and Mapping by:

Mining Corporation Exploration Dept.
arter, J. W. Norby, R. A. Brozdowski,
rgeson, R. J. Gleason, B. A. Bouley,
dder, R. C. Johnson)

dge - Corporation

Exploration, Inc., Marquette Michigan

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versity Master's Theses with Michigan
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areas from the following reports which were
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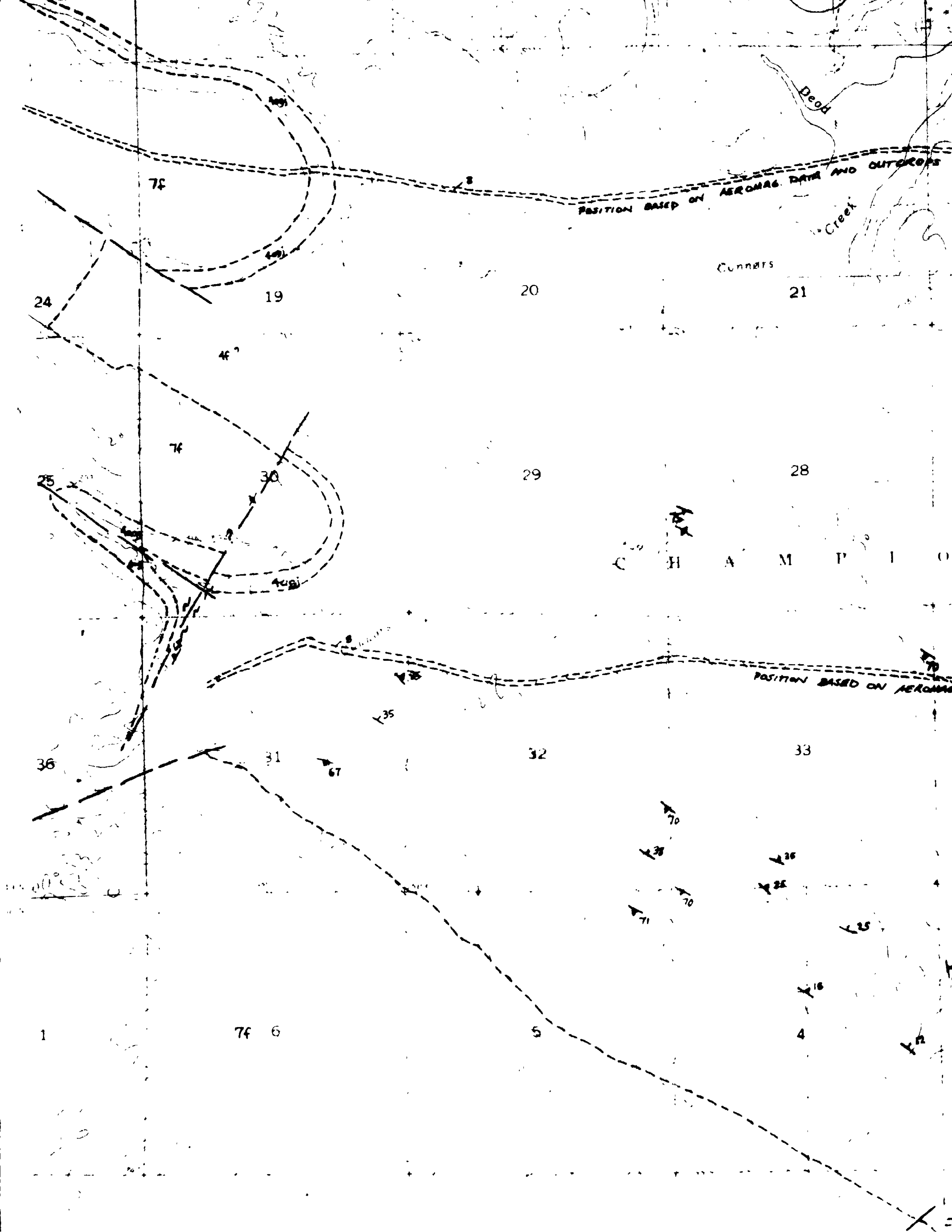
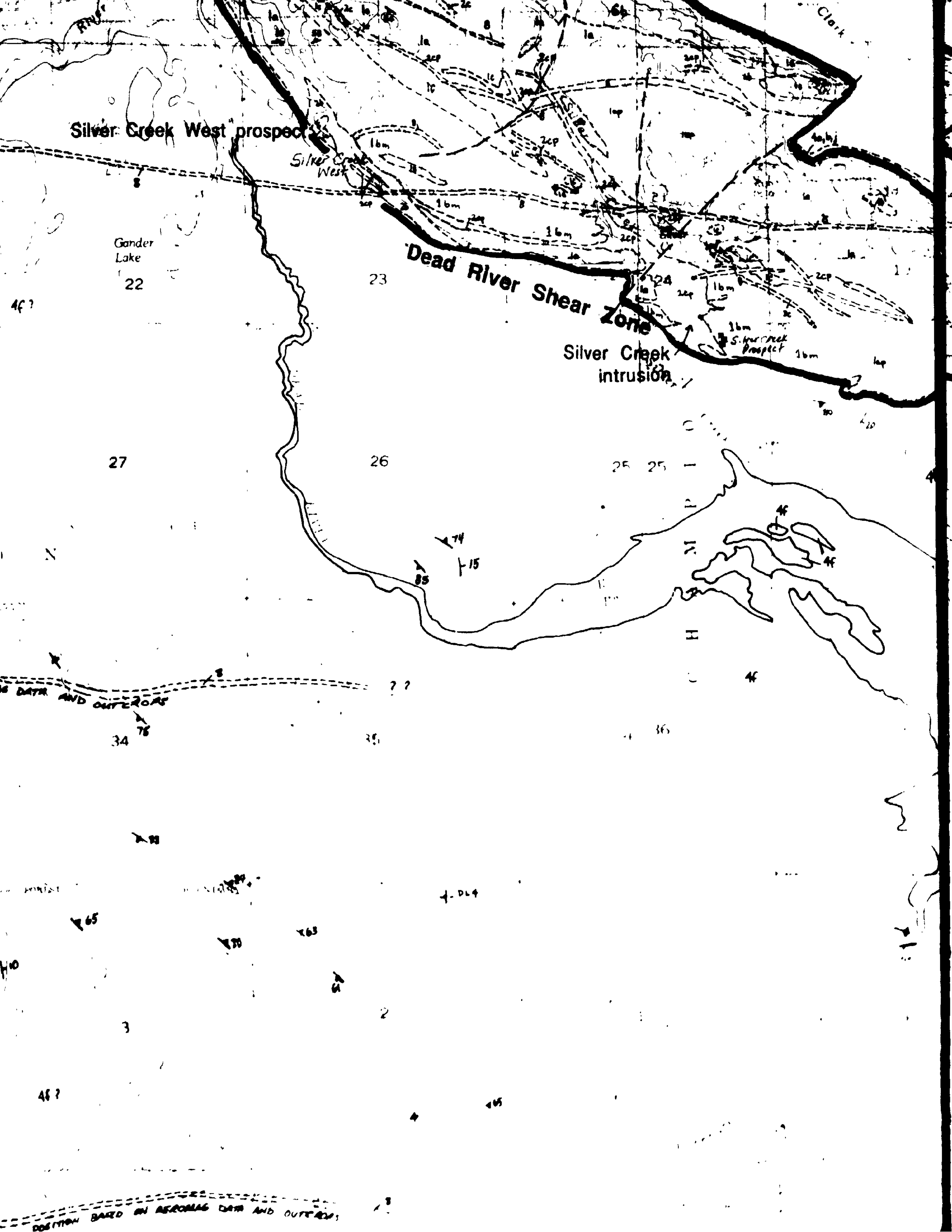
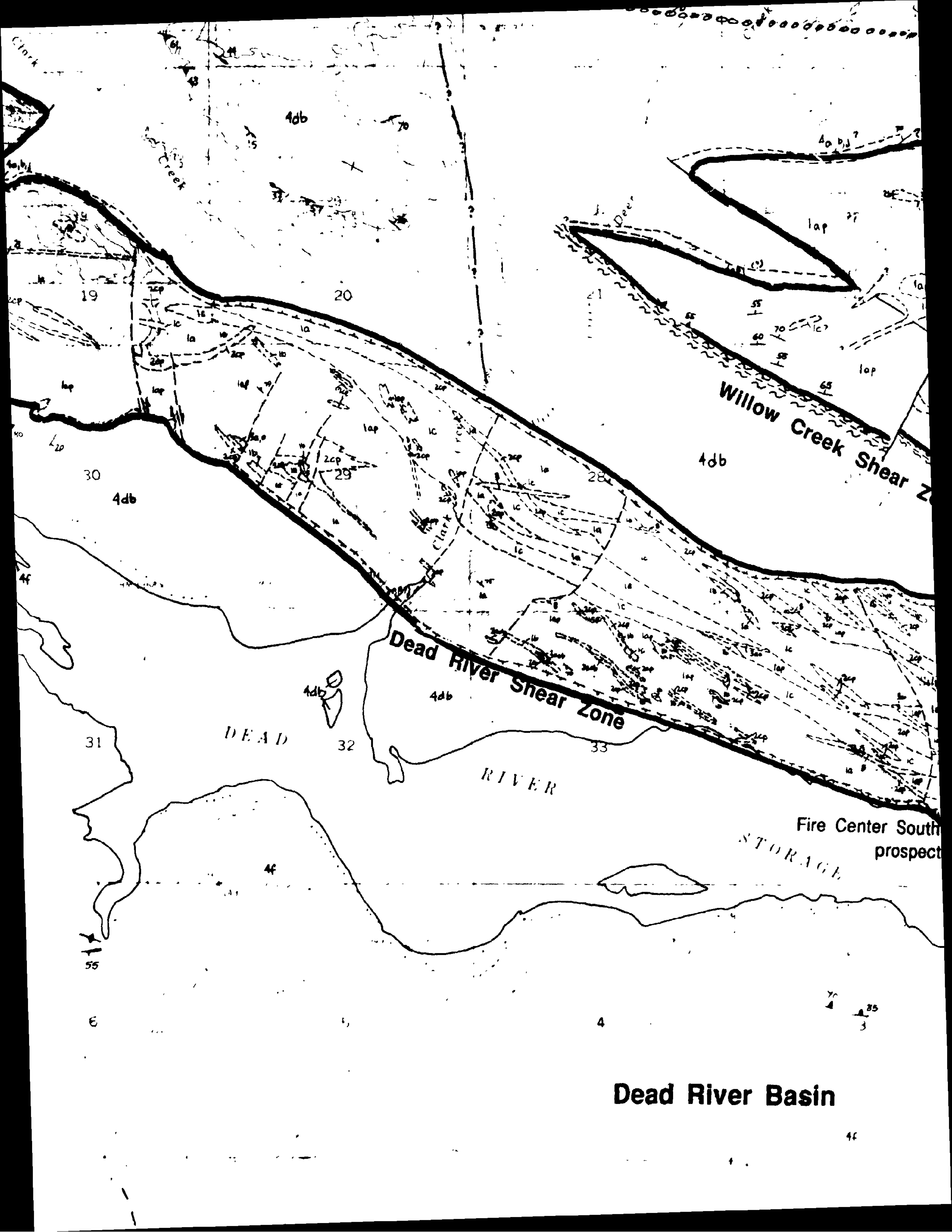
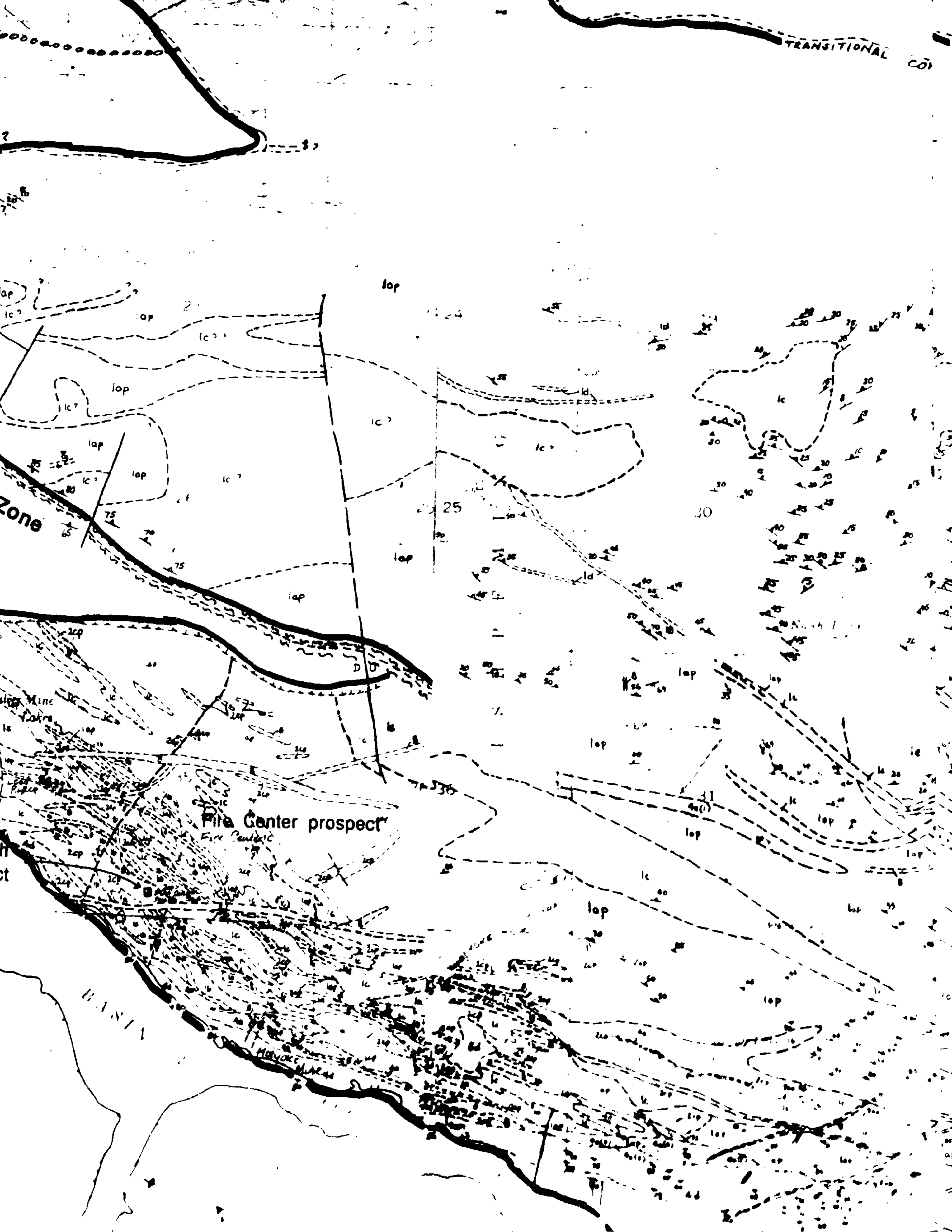
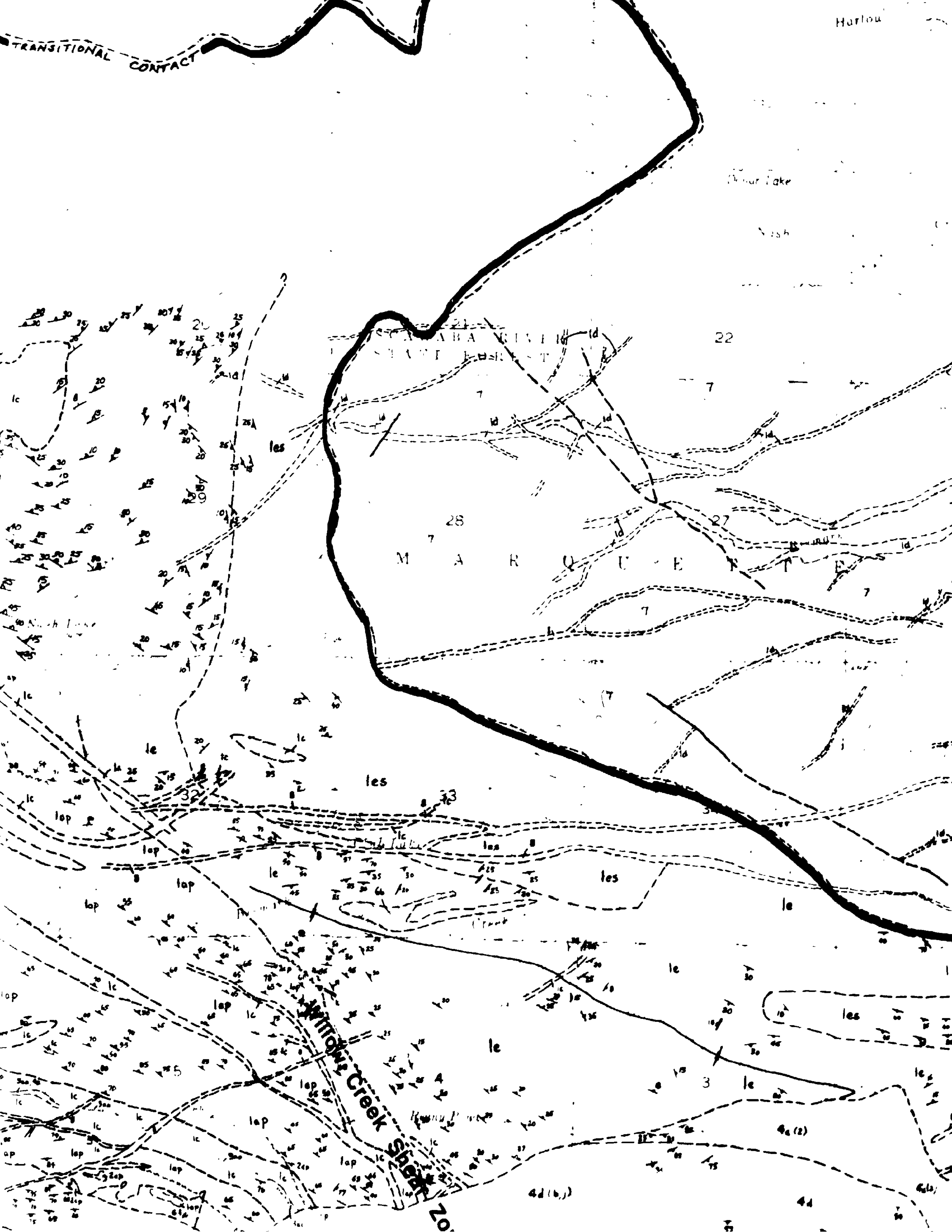


Dead
Creek
Gunnars
POSITION BASED ON AEROMAG. DATA AND OUTCROPS
POSITION BASED ON AEROMAG
C H A M P I O
7f
4f
19
20
21
24
25
30
29
28
36
31
32
33
1
6
5
4
35
67
70
71

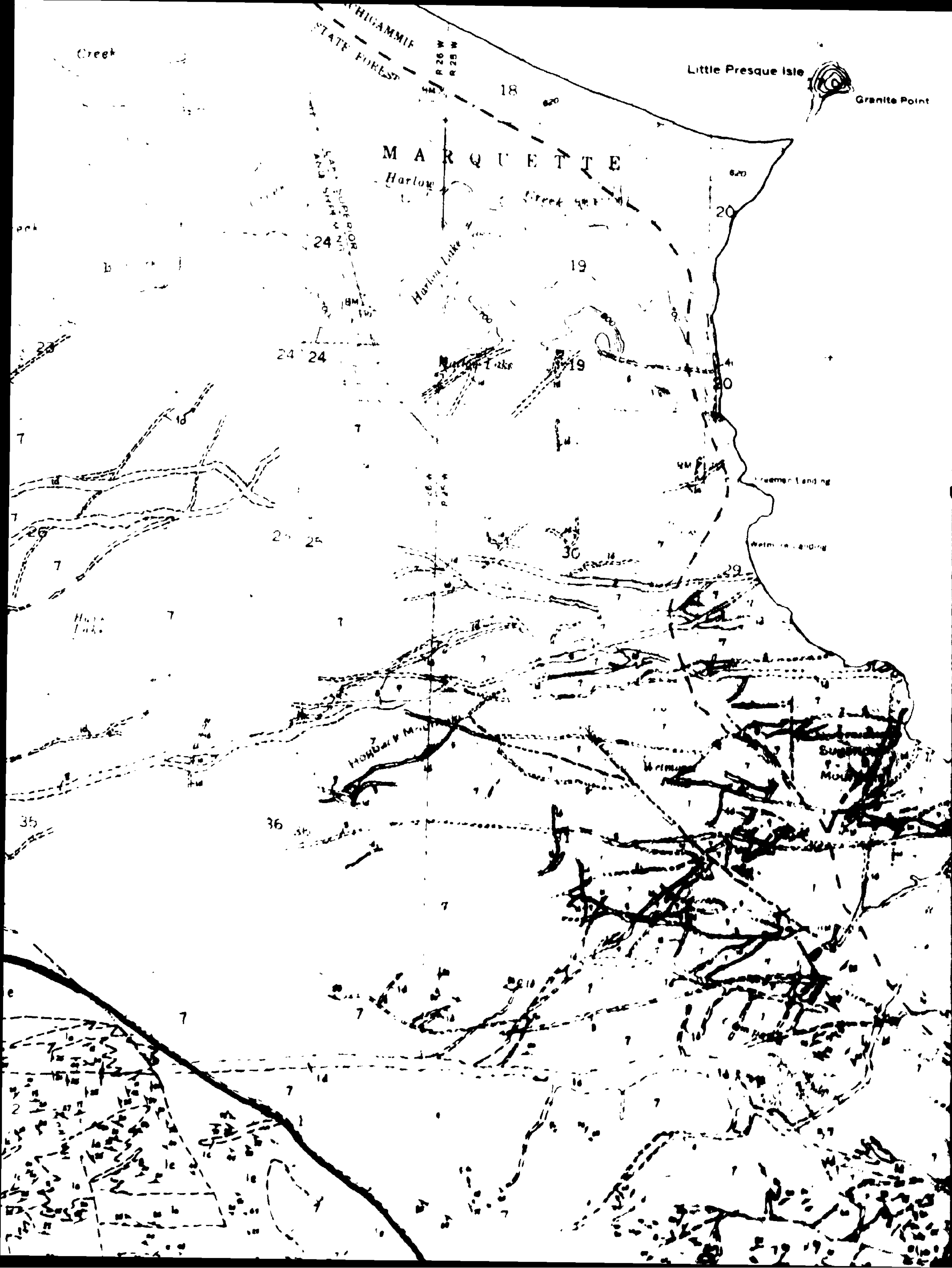

Silver Creek West prospect
Silver Creek West
Gander Lake
Dead River Shear Zone
Silver Creek intrusion
S. Silver Creek Prospect
22
23
24
25
26
27
34
35
36
2
3
DATA AND OUTCROPS
POSITION BASED ON AEROMAG DATA AND OUTCROPS


Willow Creek Shear Zone
Dead River Shear Zone
Fire Center South prospect
DEAD
RIVER
STORAGE
Clark Creek
Deer
4db
1ap
1a
1c
2cp
4f
19
20
21
28
29
30
31
32
33
4
Dead River Basin


TRANSITIONAL
Zone
Fire Center prospect



TRANSITIONAL CONTACT
Willow Creek Shear Zone
les
le
lap
lc
28
27
22
29
32
33
4
3
5
7
4d
4d (b,j)
4a (2)



Little Presque Isle
Granite Point
M A R Q U E T T E
Harlow
Creek
Harlow Lake
18
19
20
24
25
26
29
30
35
36

R = Resourc

H = Humble

Michigan Geolo
Technological
Technological Un

(Only mapp
used in thi
map.)

O = Owens
same a

B = Baxter

J = Johnson

M = Maclell

S = Small.

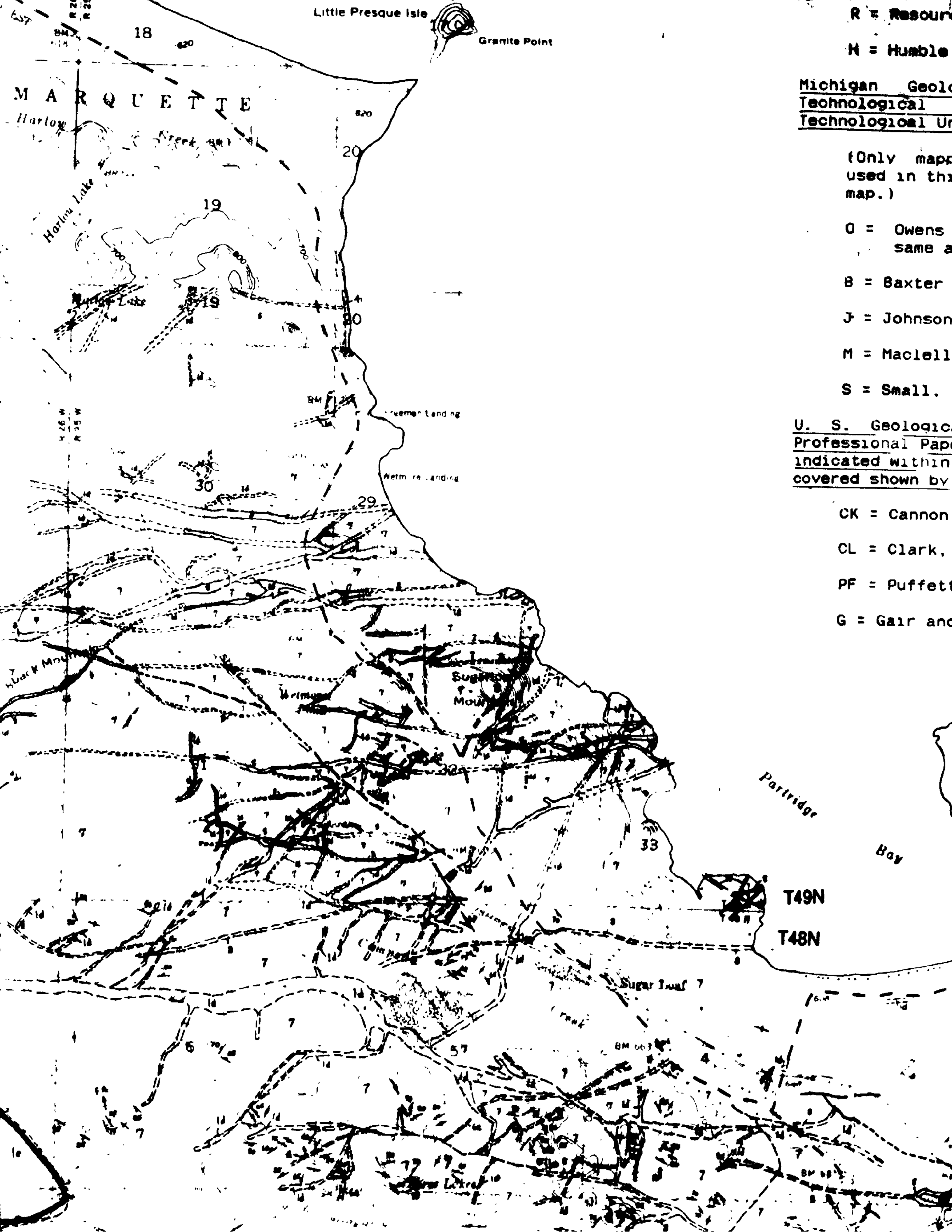
U. S. Geologica
Professional Pap
indicated within
covered shown by

CK = Cannon

CL = Clark,

PF = Puffett

G = Gair and



Exploration, Inc., Marquette Michigan

Oil Company

gical Survey Division Reports and Michigan University Master's Theses with Michigan iversity Students as primary authors:

ed areas from the following reports which were s compilation are indicated on the above index

and Bornhorst, 1985 (not used as primary source. rea covered by Callahan Mining Corp. mapping)

and others, 1987

and others, 1987

an. 1988

1989

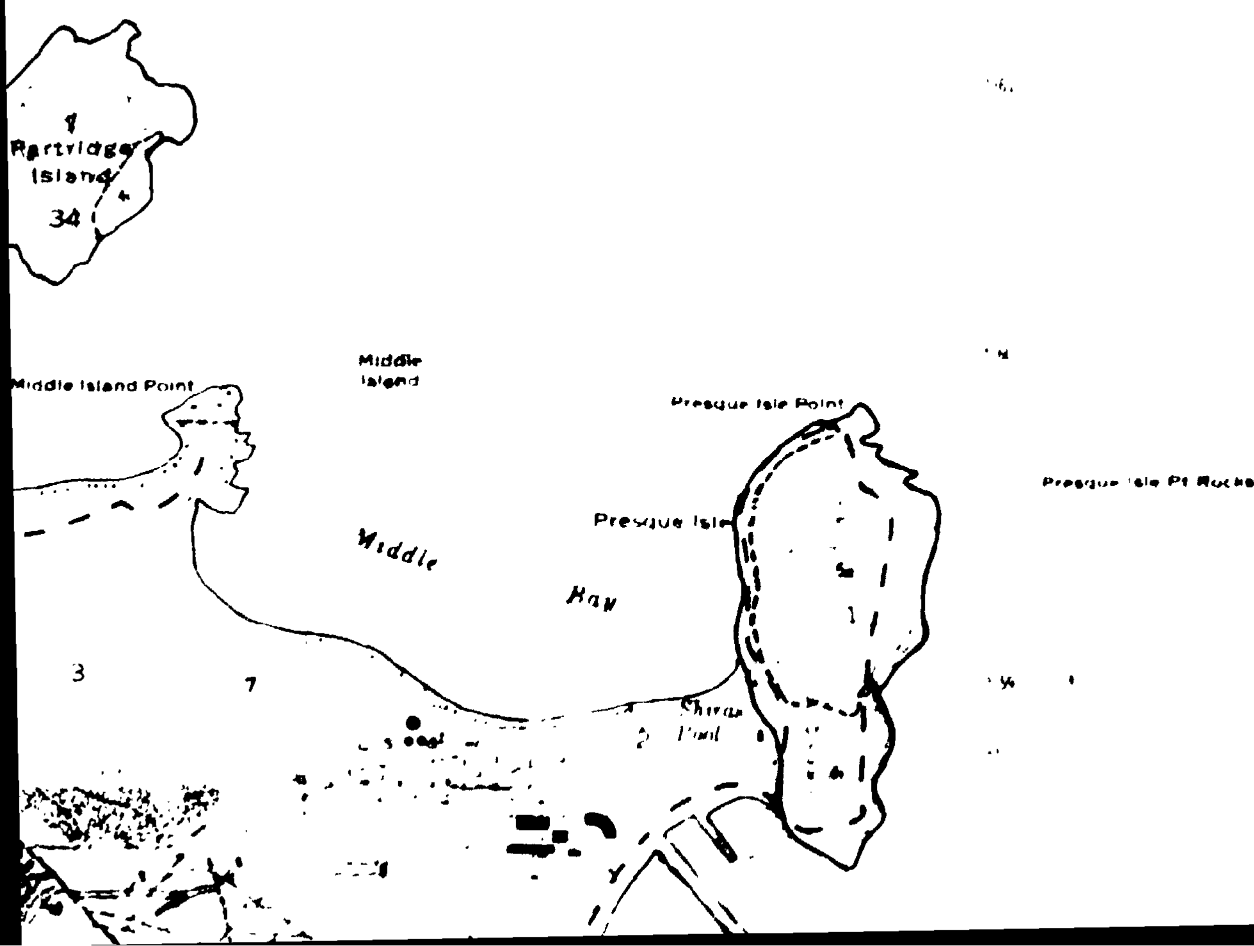
al Survey 7 1/2 Minute Quadrangle Maps and ers (Used where no other coverage is Marquette greenstone belt, total areas dashed boxes):

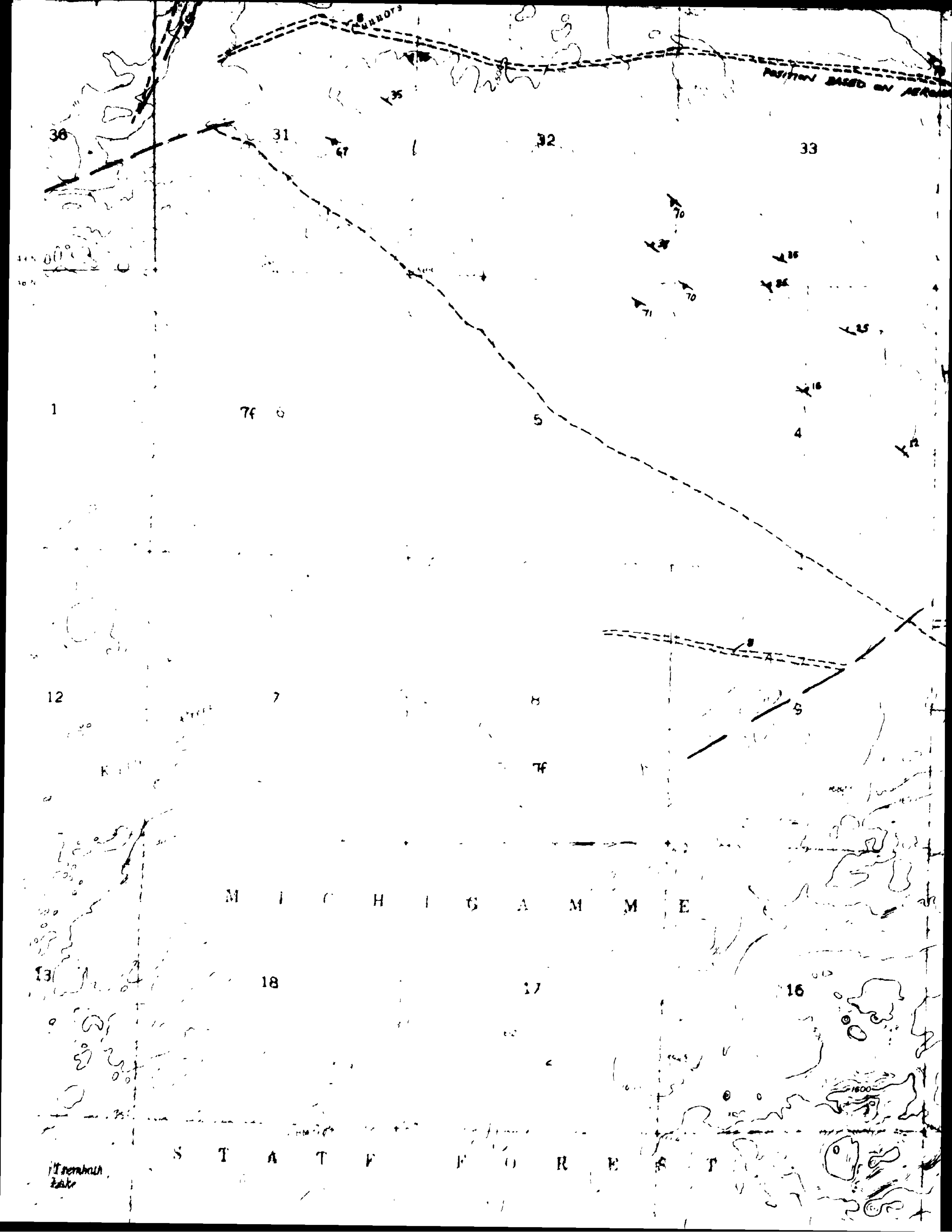
and Klasner, 1977

Cannon, and Klasner, 1975

, 1974

Thaden, 1968





POSITION BASED ON AERO
36
31
32
33
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6
5
4
12
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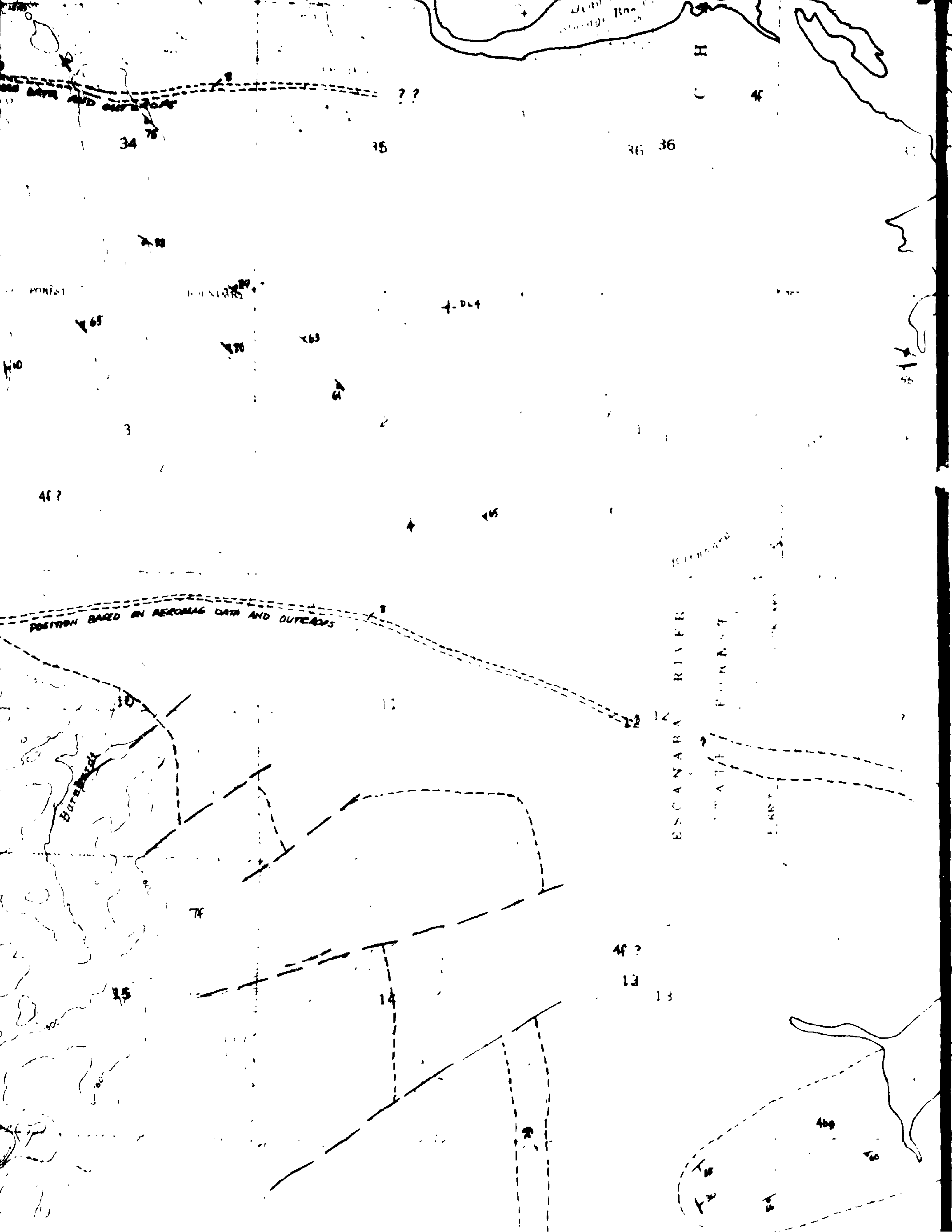
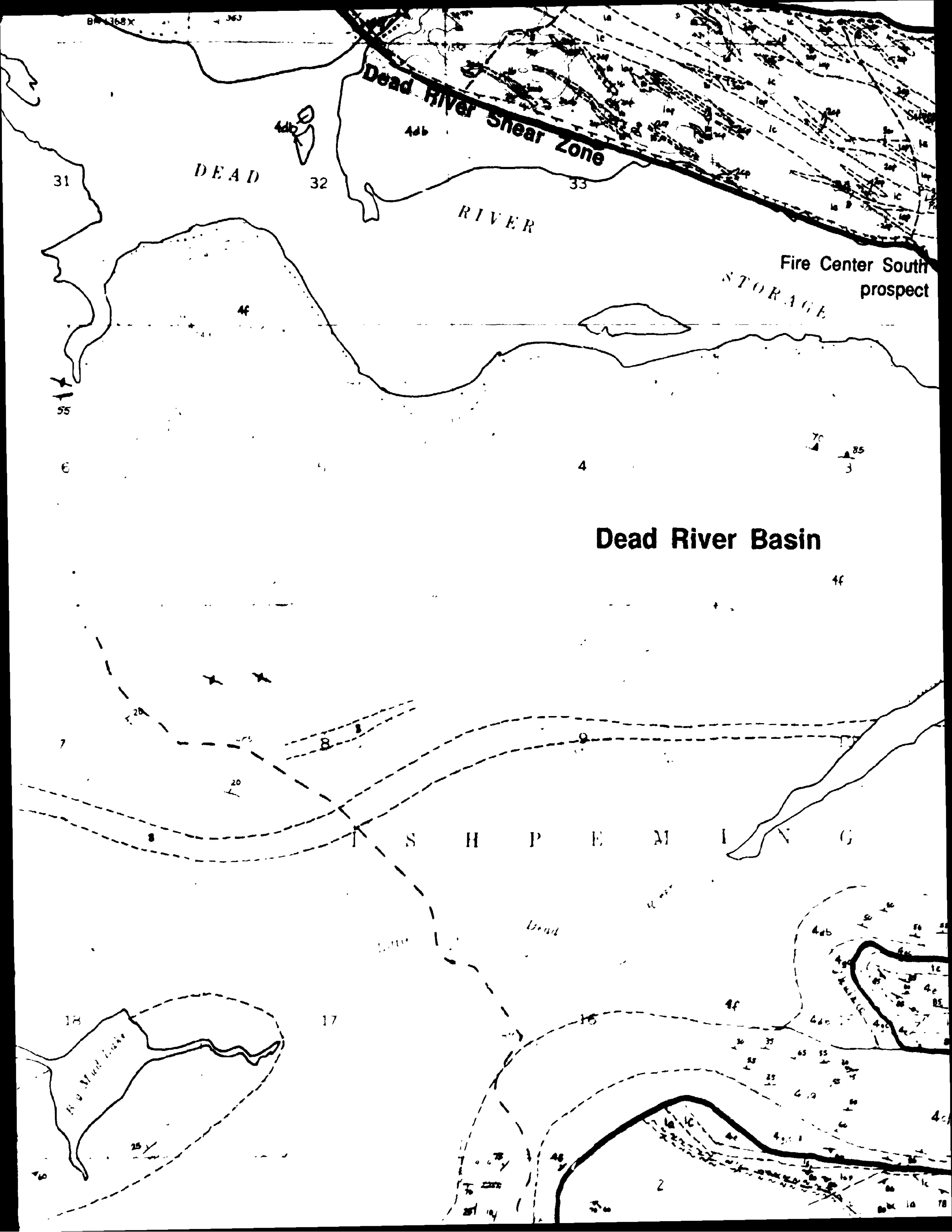
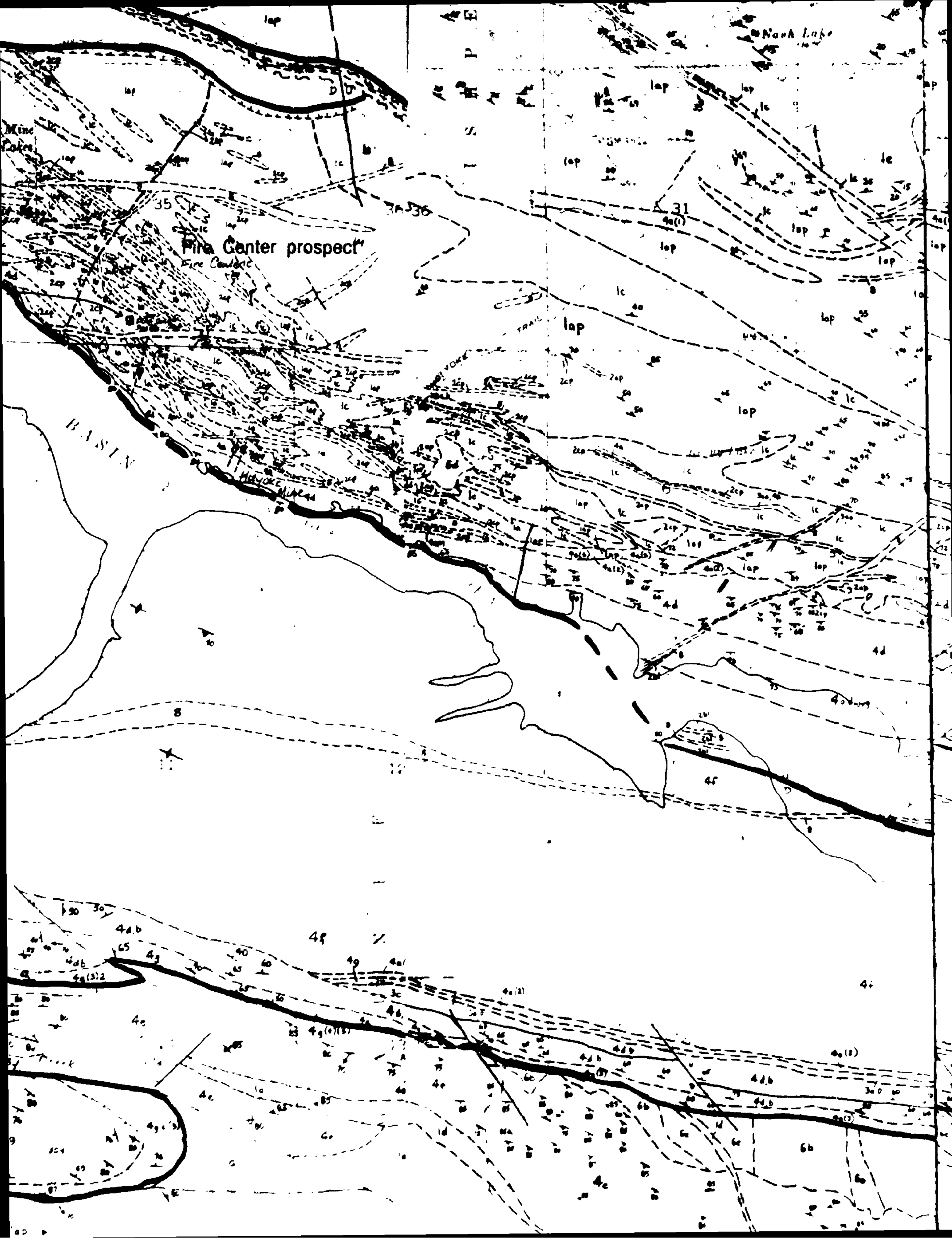
8
9
18
17
16
M I C H I G A M M E
S T A T E F O R E S T
Trembath Lake
1600



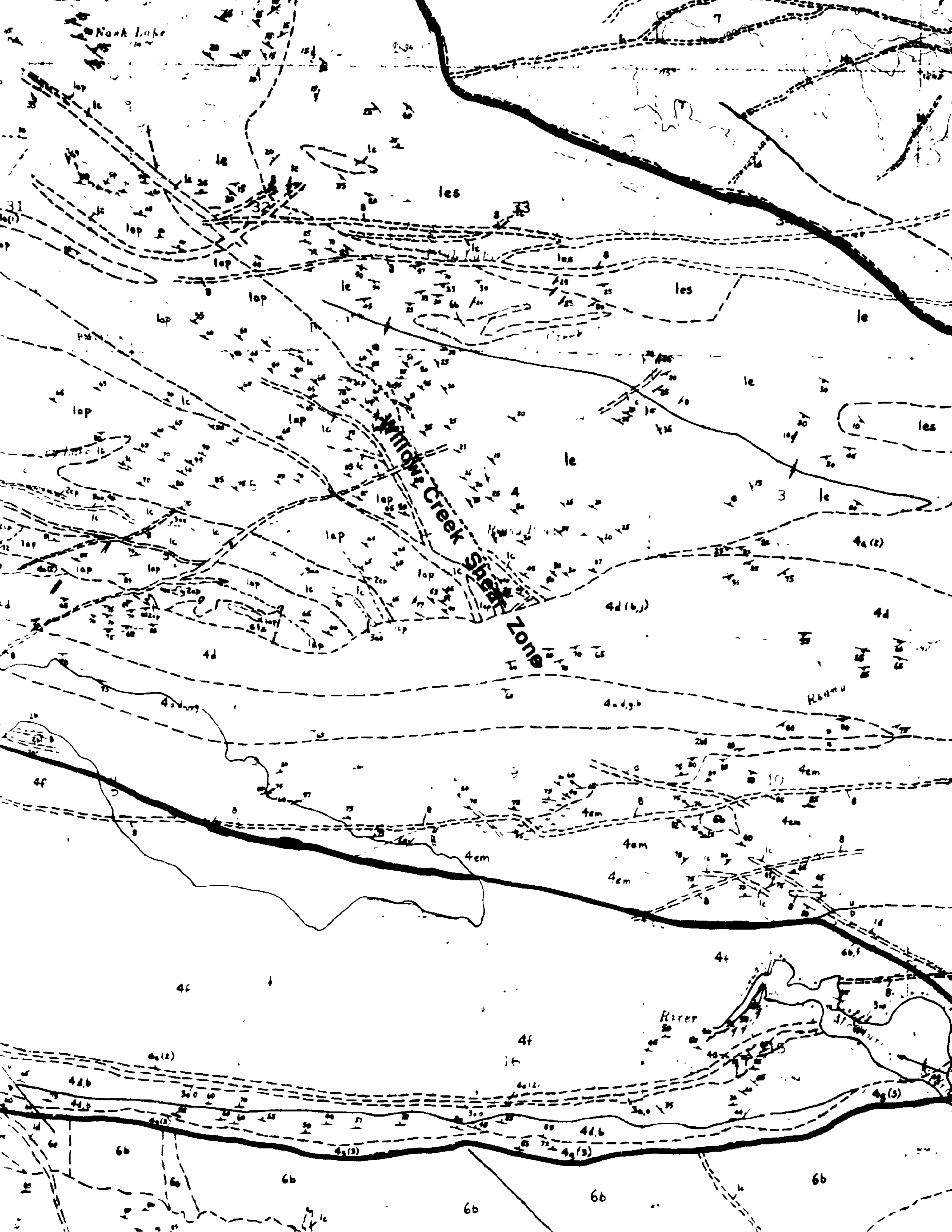
34
35
36
4f
3
2
1
4f ?
POSITION BASED ON AEROMAG DATA AND OUTCROPS
10
11
12
ESCANABA RIVER
STATE FOREST
7f
4f ?
13
14
15
4bg



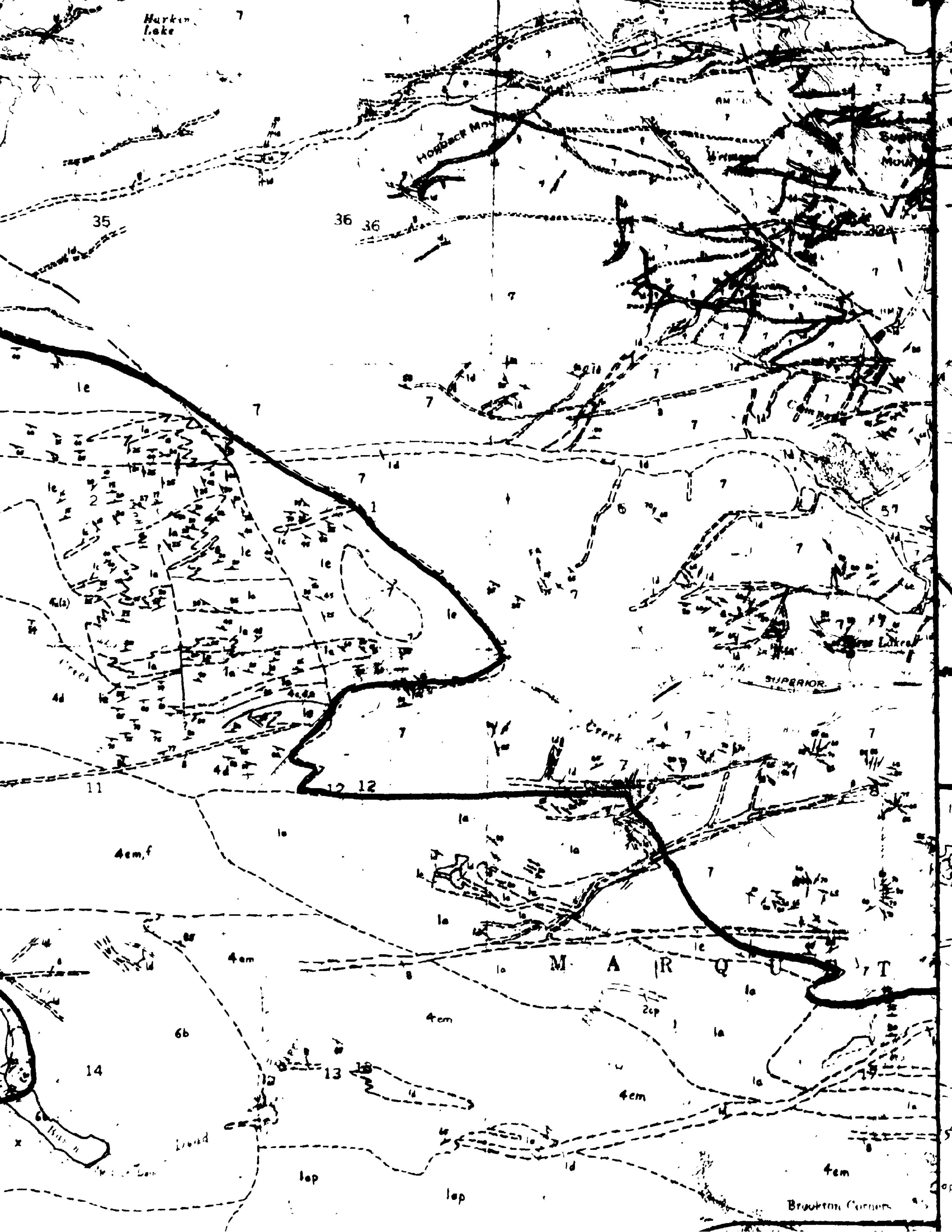
Dead River Shear Zone
DEAD
RIVER
STORAGE
Fire Center South prospect
Dead River Basin
31
32
33
4
4f
4db
I S H P E M I N G



Fire Center prospect
Nash Lake
B A S I N



Creek Shear Zone
les
le
lap
4d
4d (b,j)
4a (2)
4em
4f
4d,b
4g (3)
6b
River

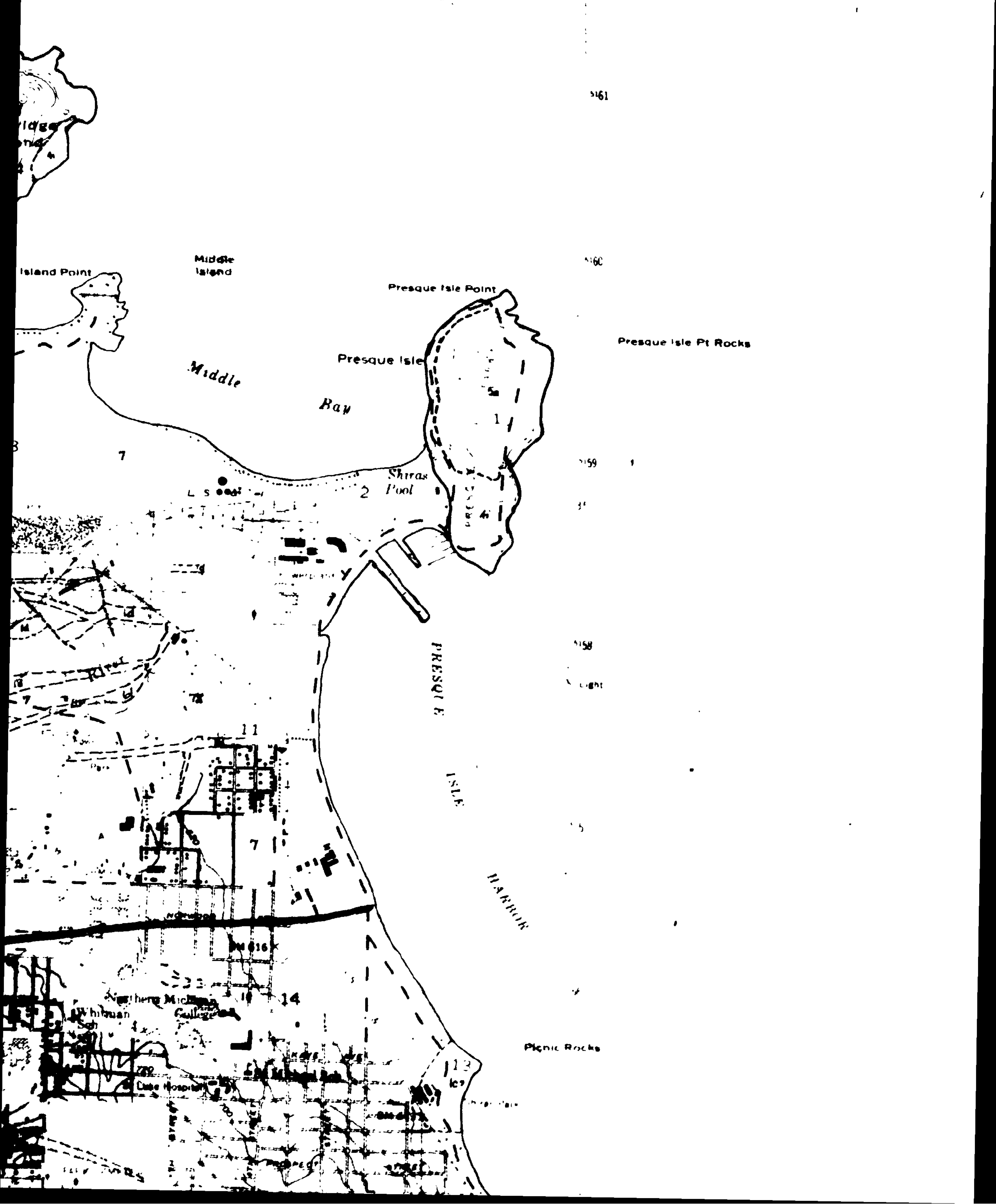


Creek
SUPERIOR
M A R Q U T
Brookton Corners

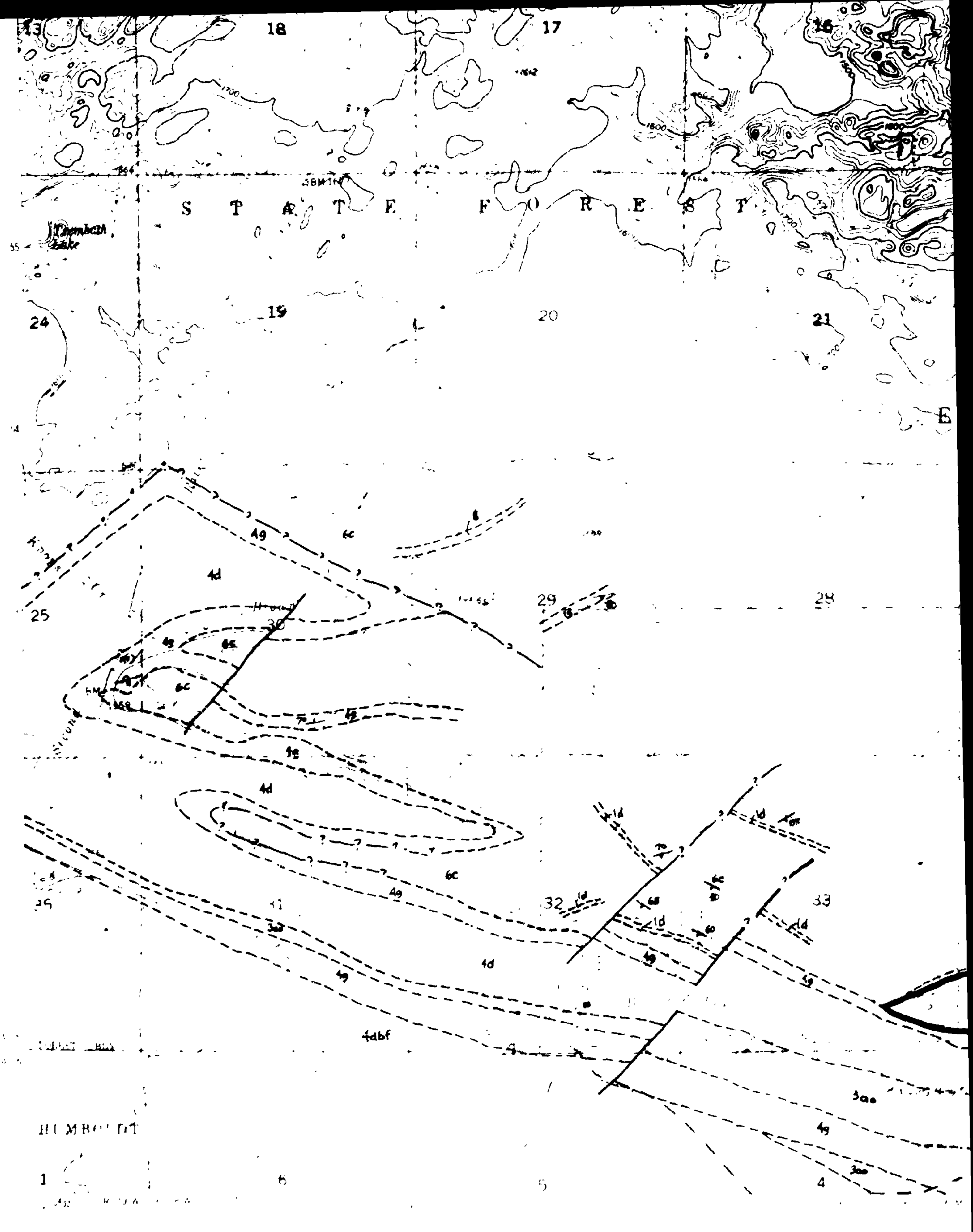

PF = Puffett, 19
G = Gair and Tha
Partridge Bay
T49N
T48N
Sugar Loaf
Creek
SUPERIOR
Creek
Sand Pit
Surge Tank
Power Sta
Dead
M A R Q U E T T E
4em
Brookton Corners
Middle
Cemetery

74

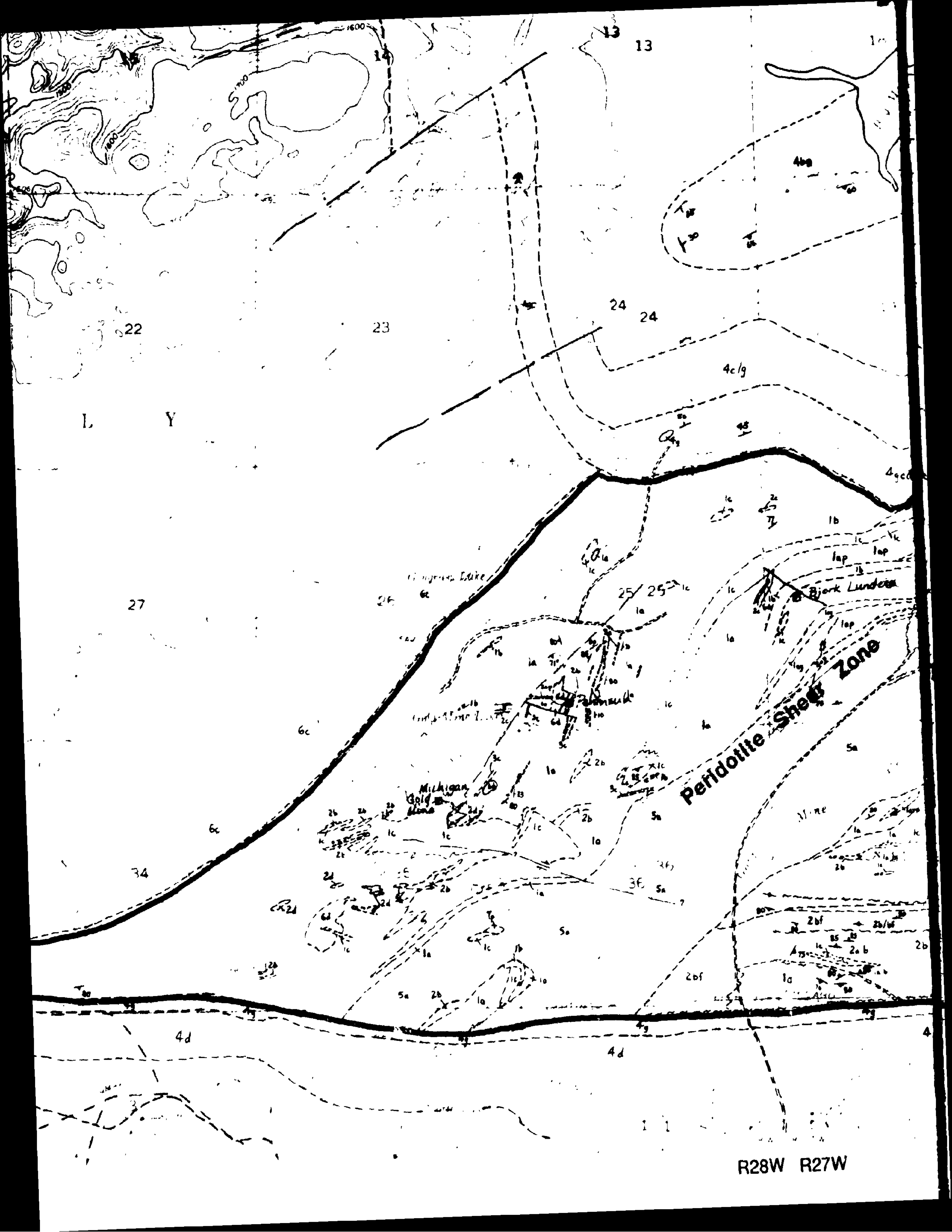
den, 1968



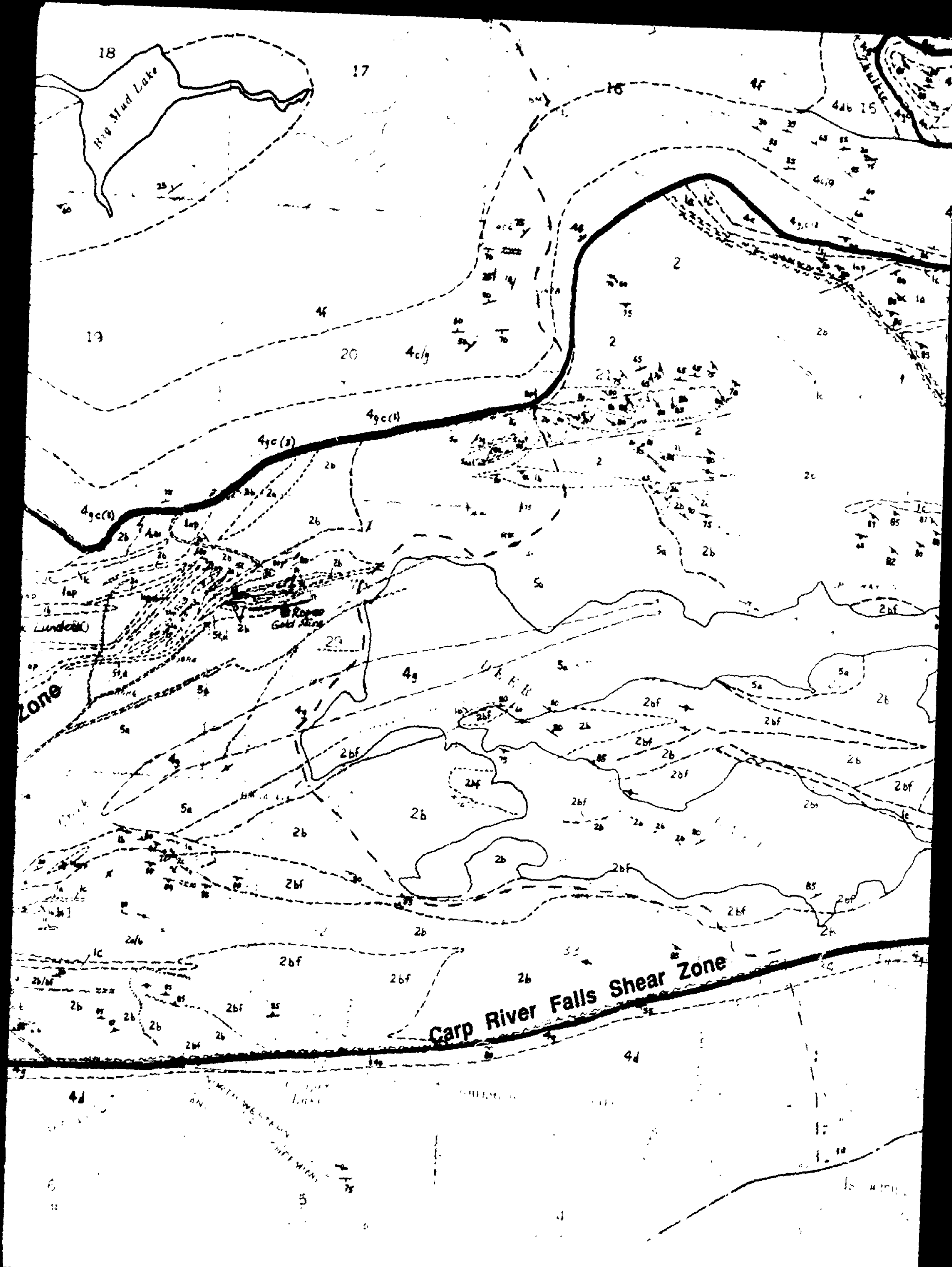
Island Point
Middle Island
Presque Isle Point
Presque Isle Pt Rocks
Presque Isle
Middle Bay
Shiras Pool
PRESQUE ISLE HARBOR
Light
Picnic Rocks
Northern Michigan College
Whitman Sch
5161
5160
5159
5158



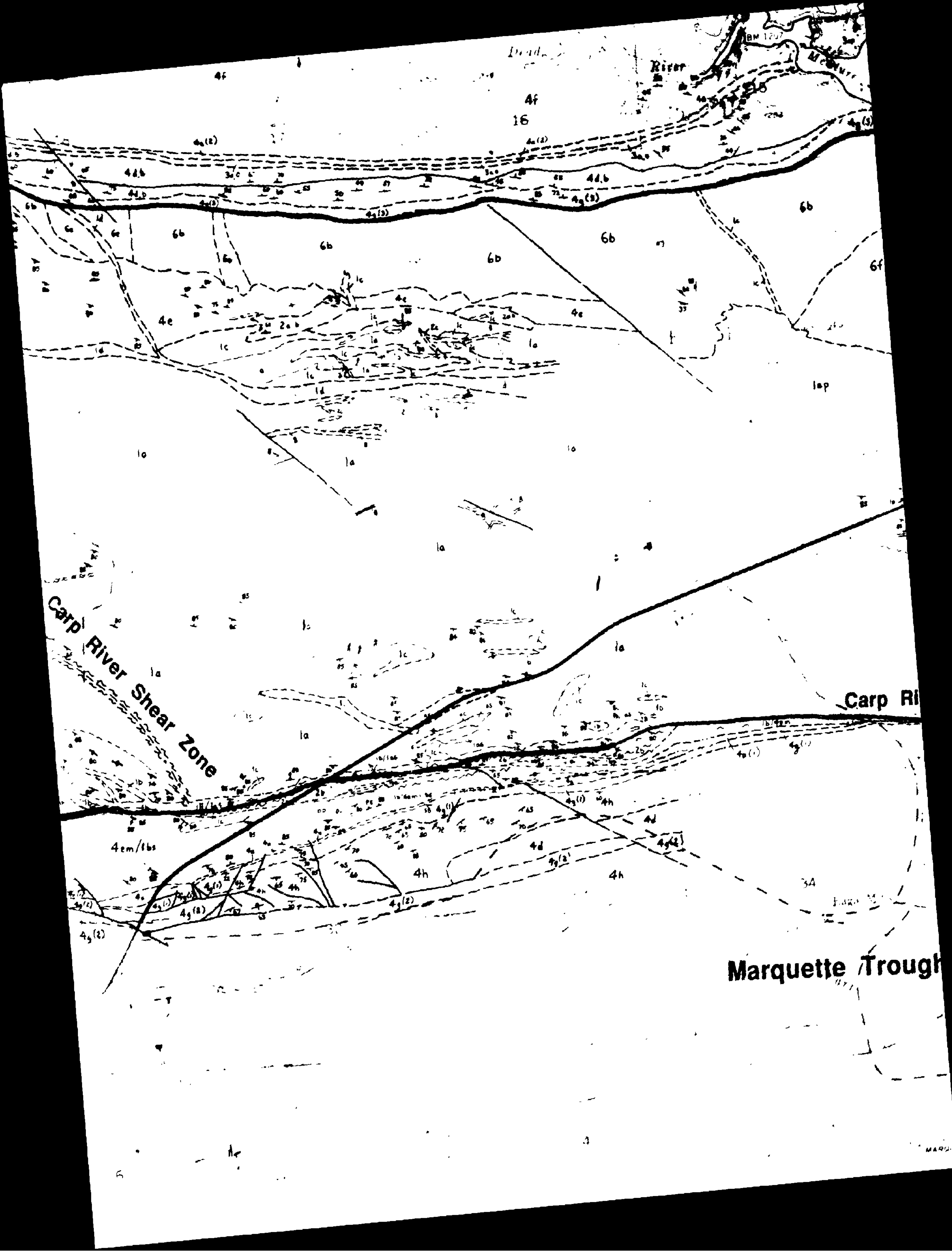
13
18
17
16
S T A T E F O R E S T
24
19
20
21
25
29
28
30
4d
4g
6c
31
32
33
4dbf
3aa
HUMBOLDT
1
6
5
4



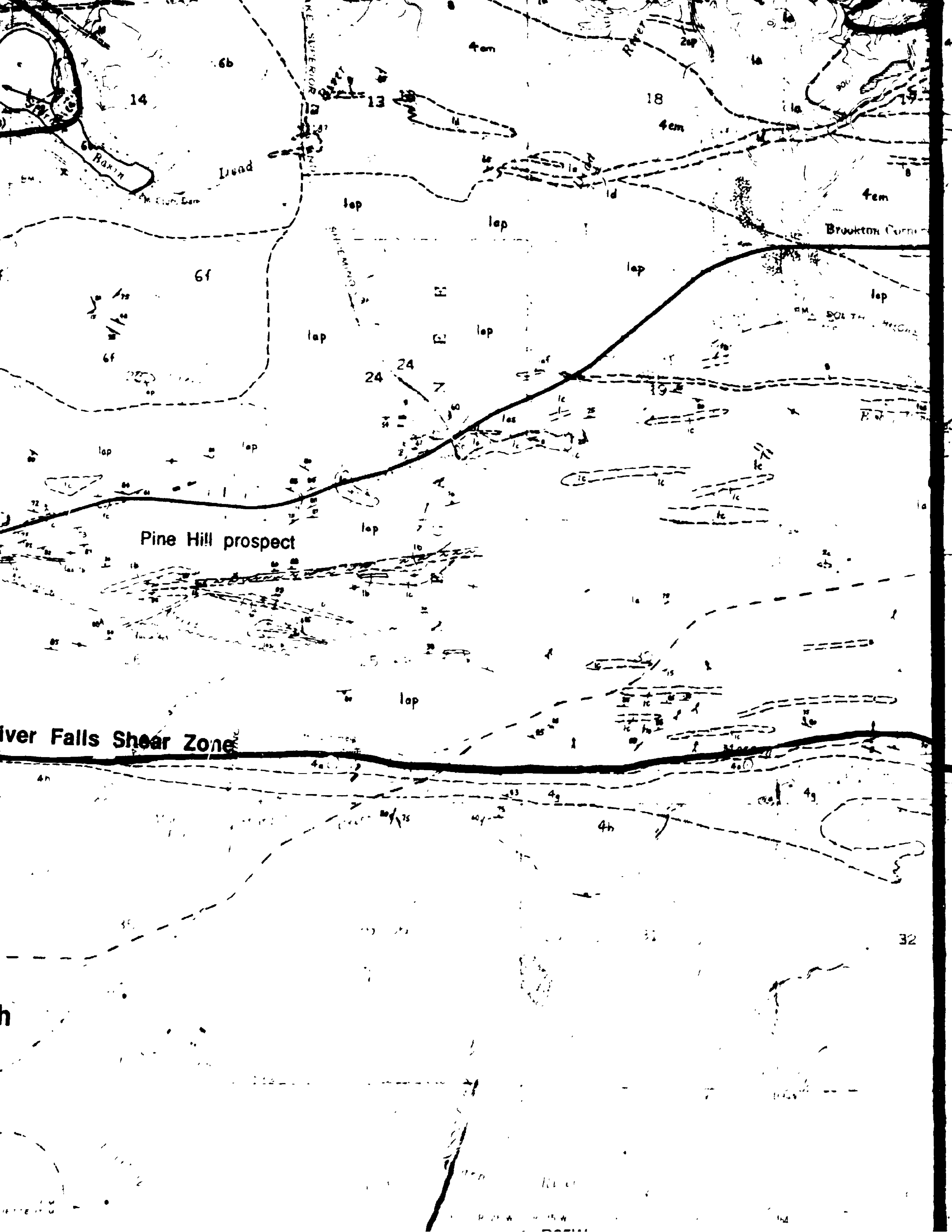
13
13
14
4bg
24
24
22
23
4c/g
L
Y
4_{gc}
1b
lap
lap
Bjork Lundeen
25
25
27
26
6c
1a
1c
Peridotite Shear Zone
6c
5a
Michigan Gold Mine
2b
1a
6c
34
36
5a
2d
2bf
2b/bf
2b
1a
5a
4d
4d
R28W R27W


Big Mud Lake
18
17
16
15
19
20
21
4f
4db
4c/g
4gc(1)
4gc(2)
2
2b
2c
5a
4g
2bf
4d
Ropes Gold Mine
Zone
Carp River Falls Shear Zone

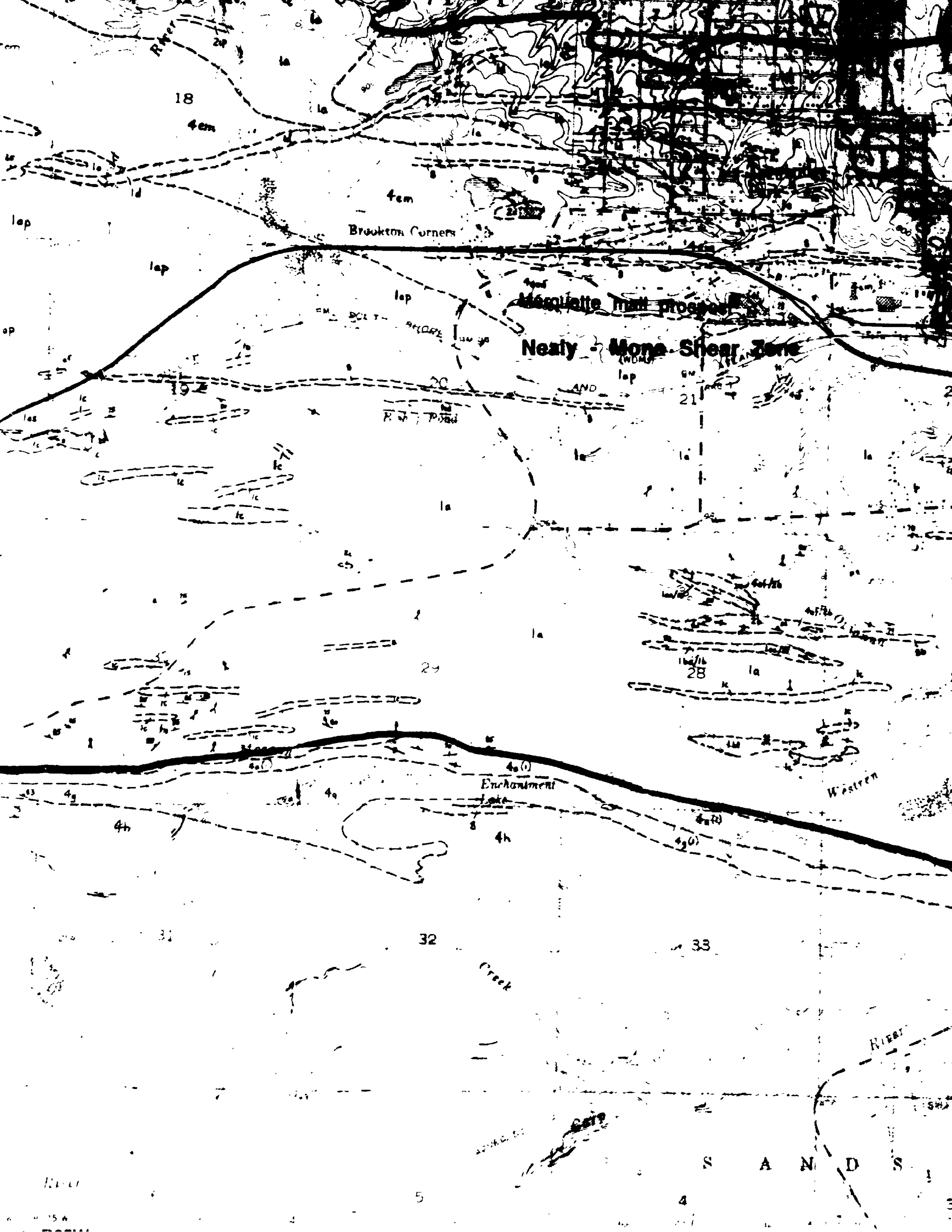
Carp River Shear Zone
Carp River Shear Zone
Creek
4e
4c/g
4d
4d.b
6b
6a
6c
1a
1c
1d
1ap
2b
2bf
2b, 2a, 2c
4em/lbs
4g(2)
4h
13
R27W
R26W



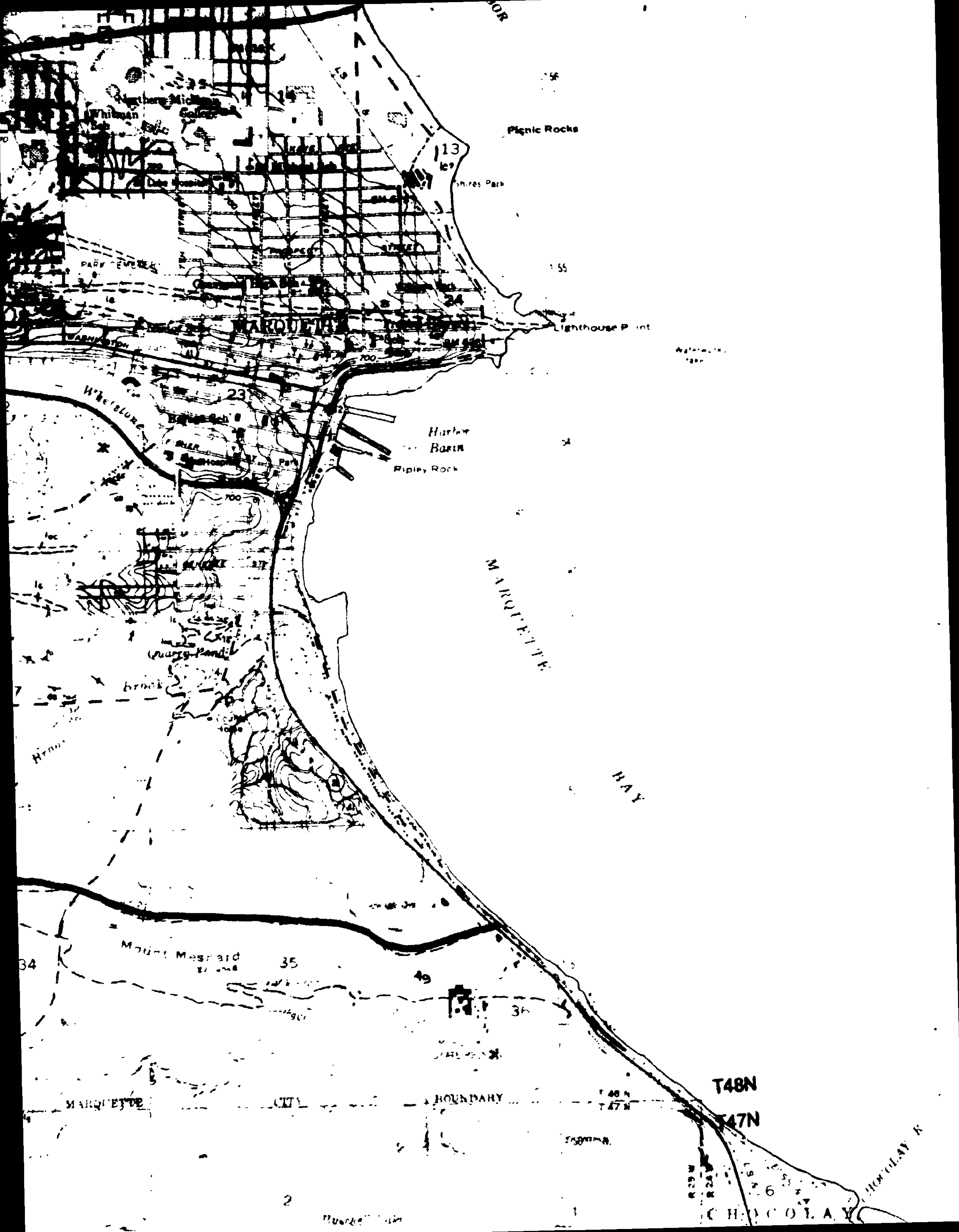
River
Carp River Shear Zone
Carp Ri
Marquette Trough



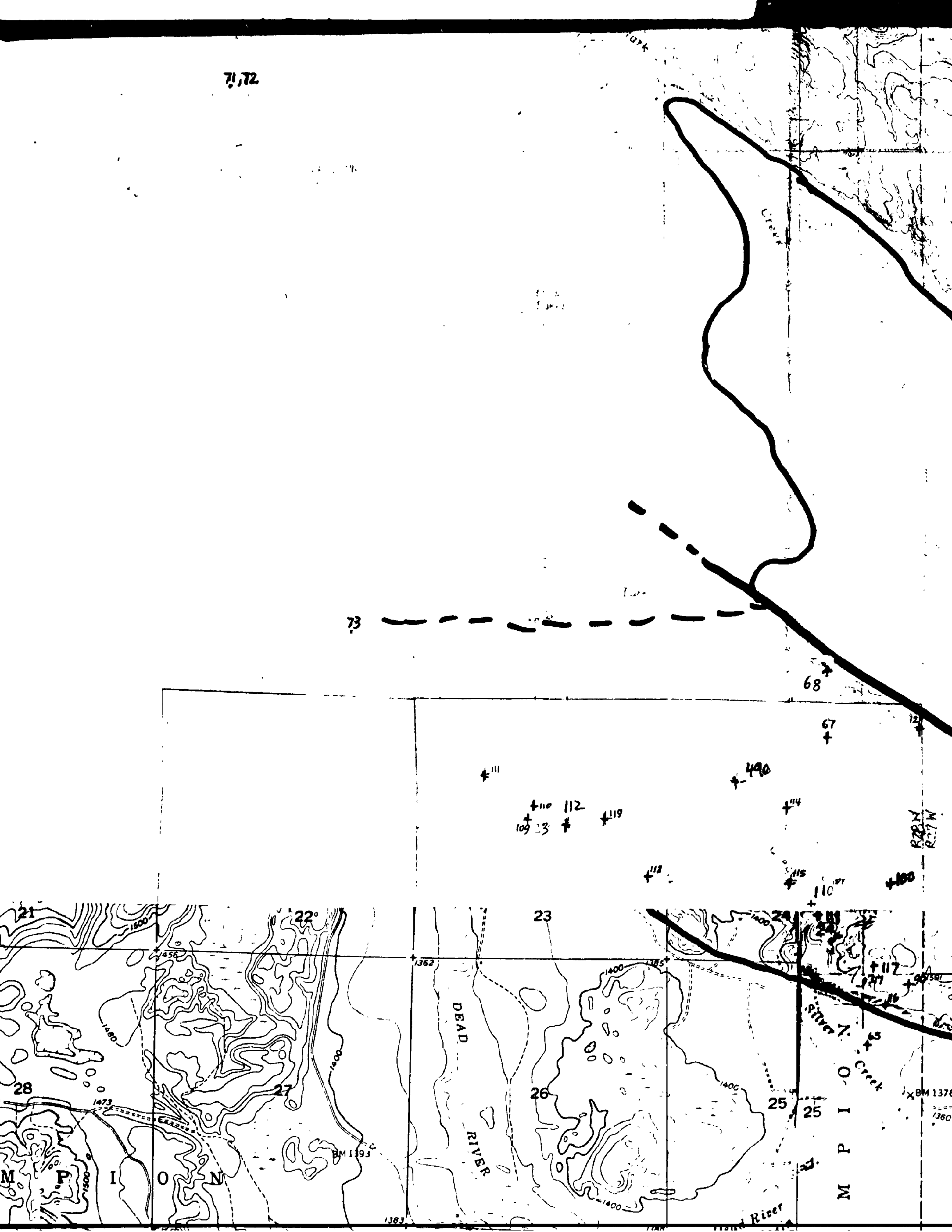
Pine Hill prospect
iver Falls Shear Zone
Brookton Corner
14
13
18
24
19
32
6b
6f
4em
lap
Dead
Basin
4h
4g



River
18
4em
Brookton Corners
Mesquette mall prospect
Nealy - Mona Shear Zone
lap
19
20
21
Fish Pond
la
29
28
Enchantment
Lake
4h
Western
31
32
33
Creek
River
S A N D S
5
4



Picnic Rocks
Shiras Park
Lighthouse Point
MARQUETTE
Harbor Basin
Ripley Rock
MARQUETTE BAY
Quarry Pond
Mount Mesnard
MARQUETTE CITY BOUNDARY
T48N
T47N
CHOCOLAY


71,72
73
68
67
490
112
110
109
119
114
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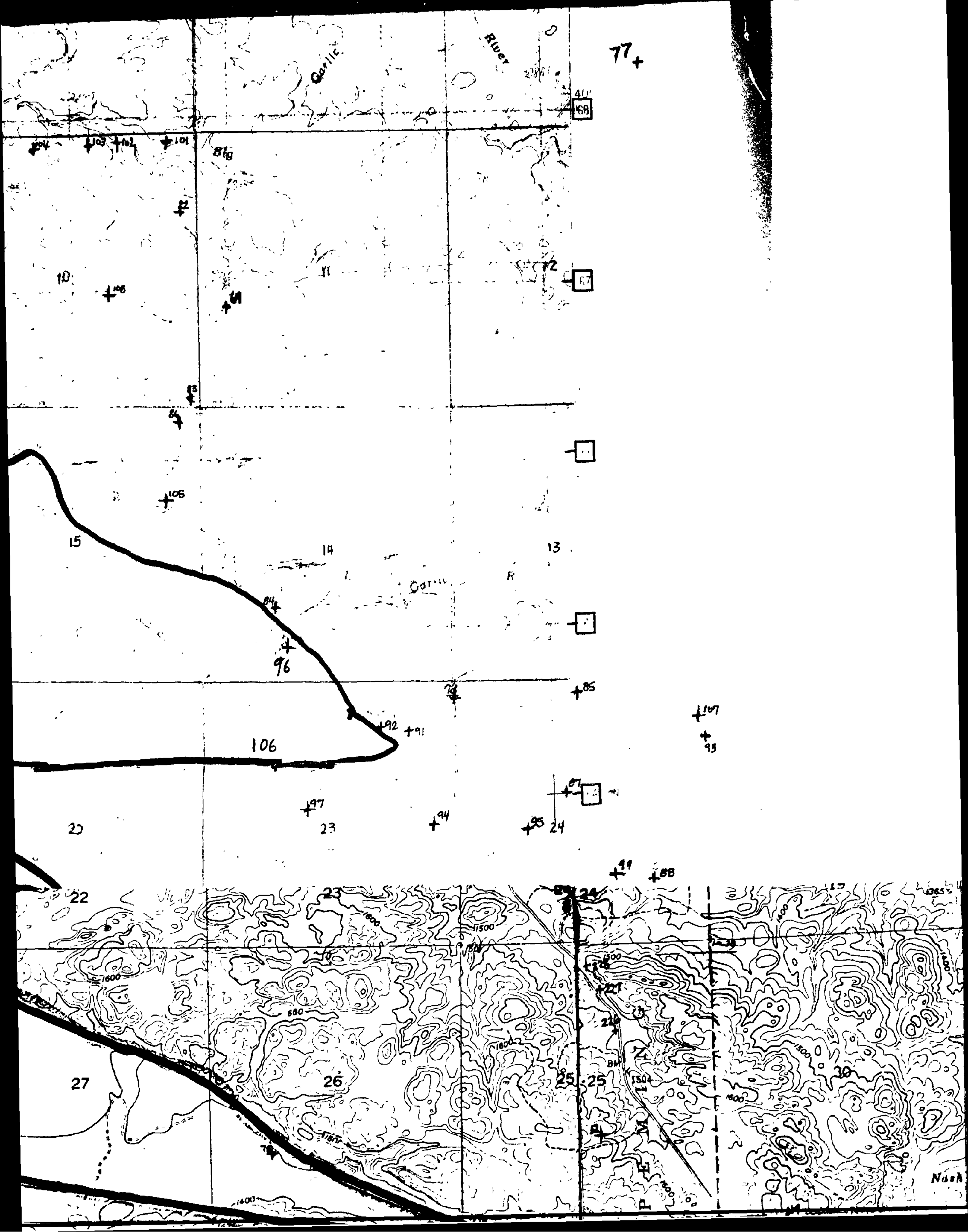
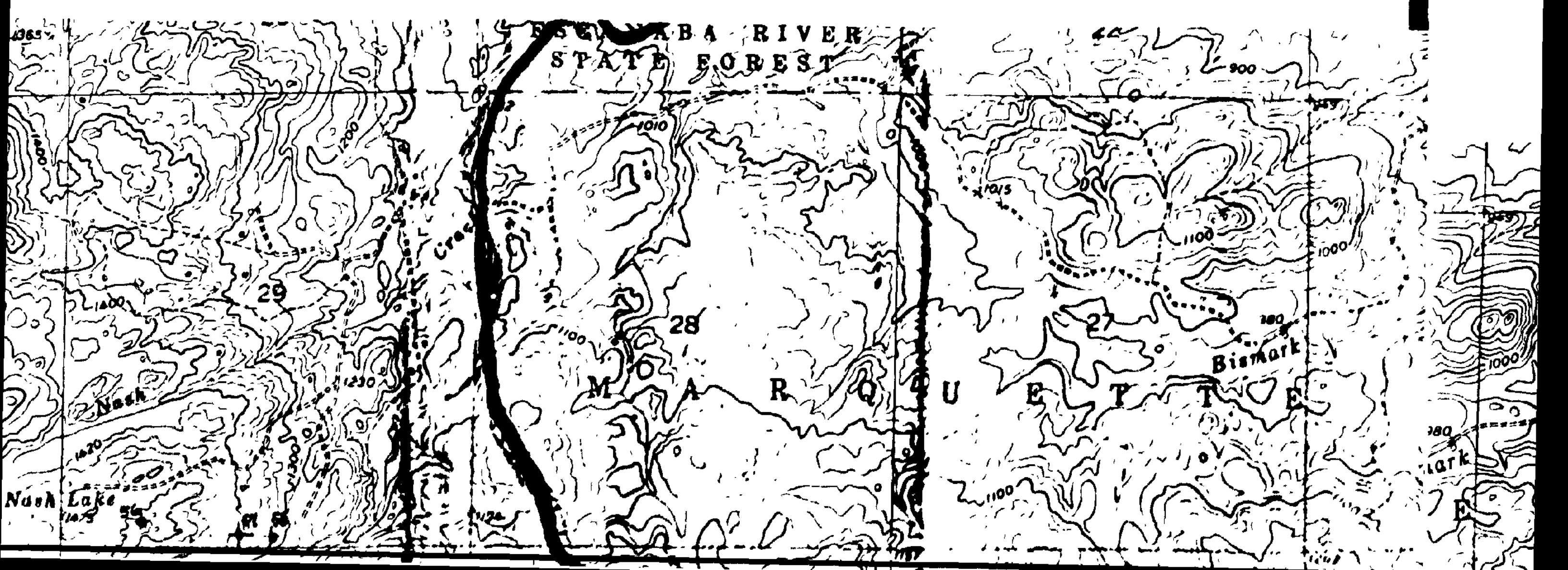
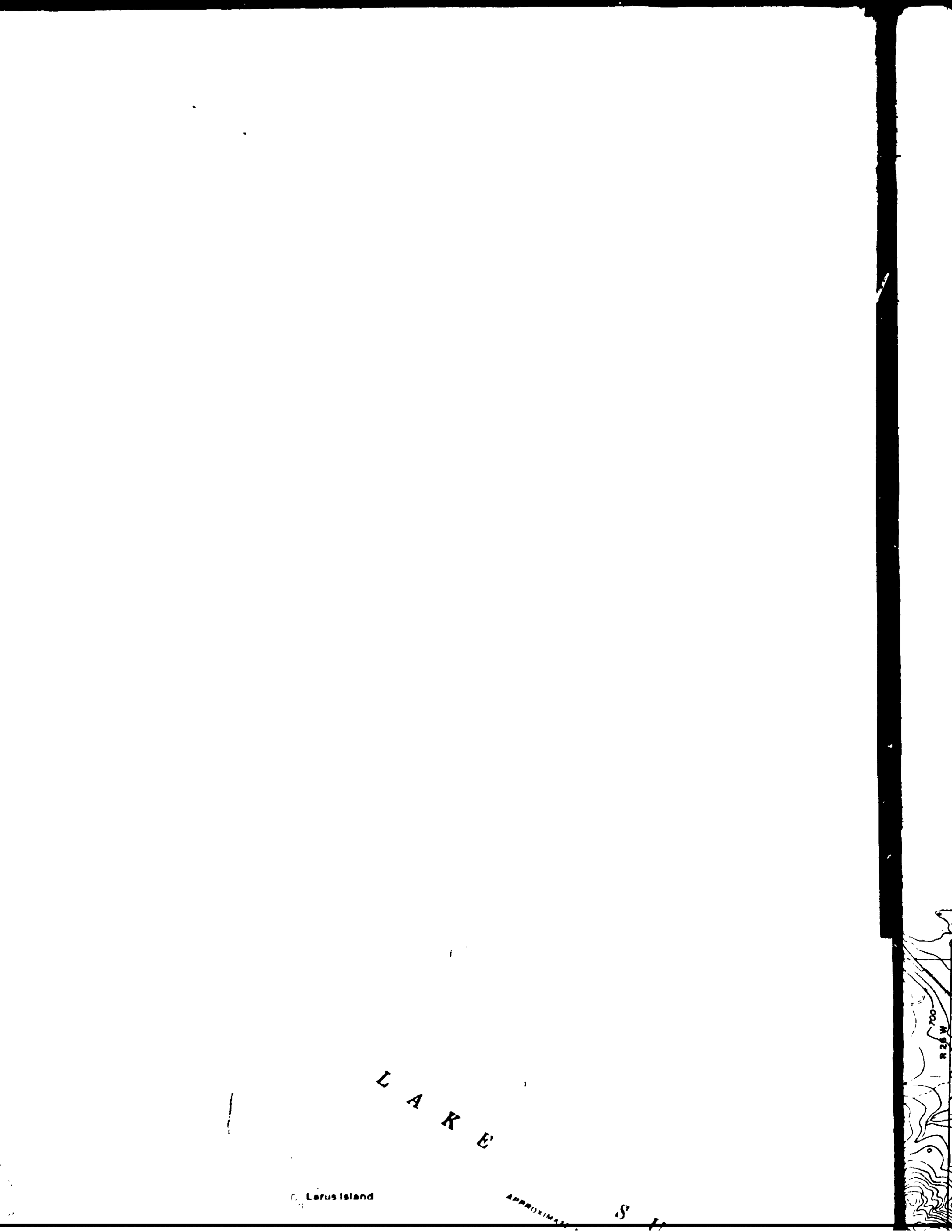
110
100
21
22
23
24
28
27
26
25
25
1500
1480
1456
1362
1385
1400
1473
BM 1393
DEAD
RIVER
Silver
Creek
BM 1376
1360
117
65
1383
Dead River
M P I O N
M P I O
Creek
R28W
R27W

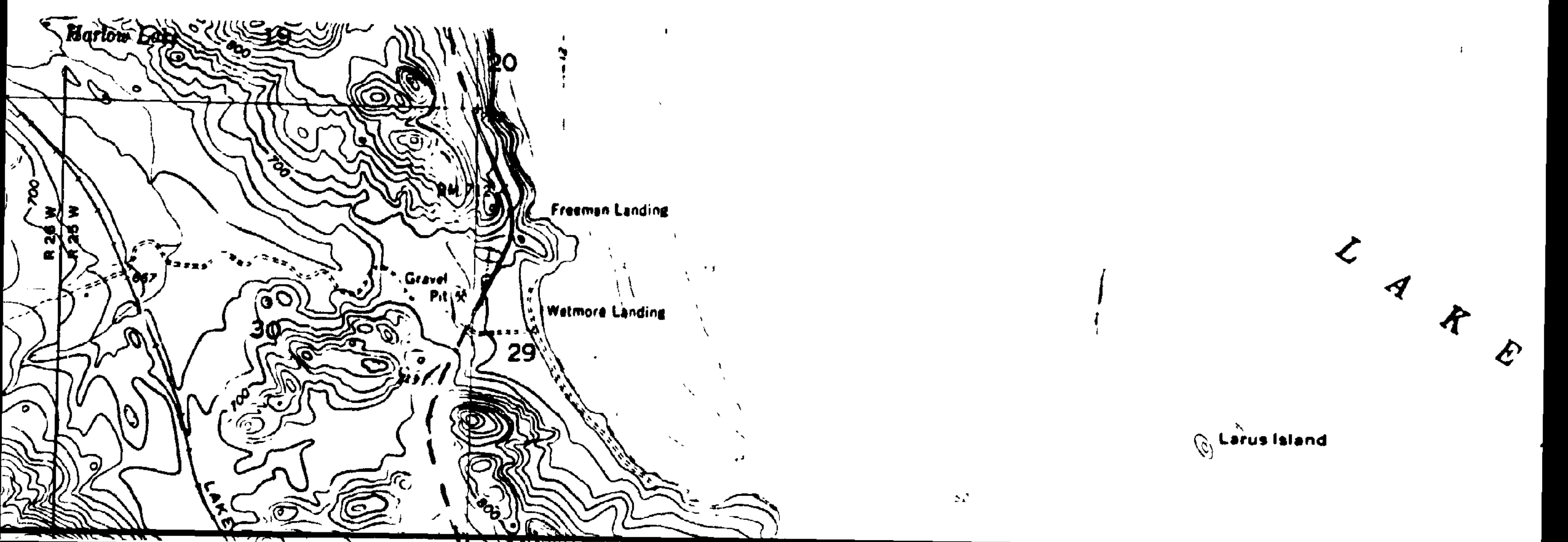

70
Boise
S
19
20
21
Creek
Cr
BM 1364
Boise
Deer
S
1600
1500
30
29
Clark
Creek
BM 1376
1370
BM 1368X


Garlic
River
77
10
15
14
13
106
96
23
24
22
27
26
25
30
1600
1500

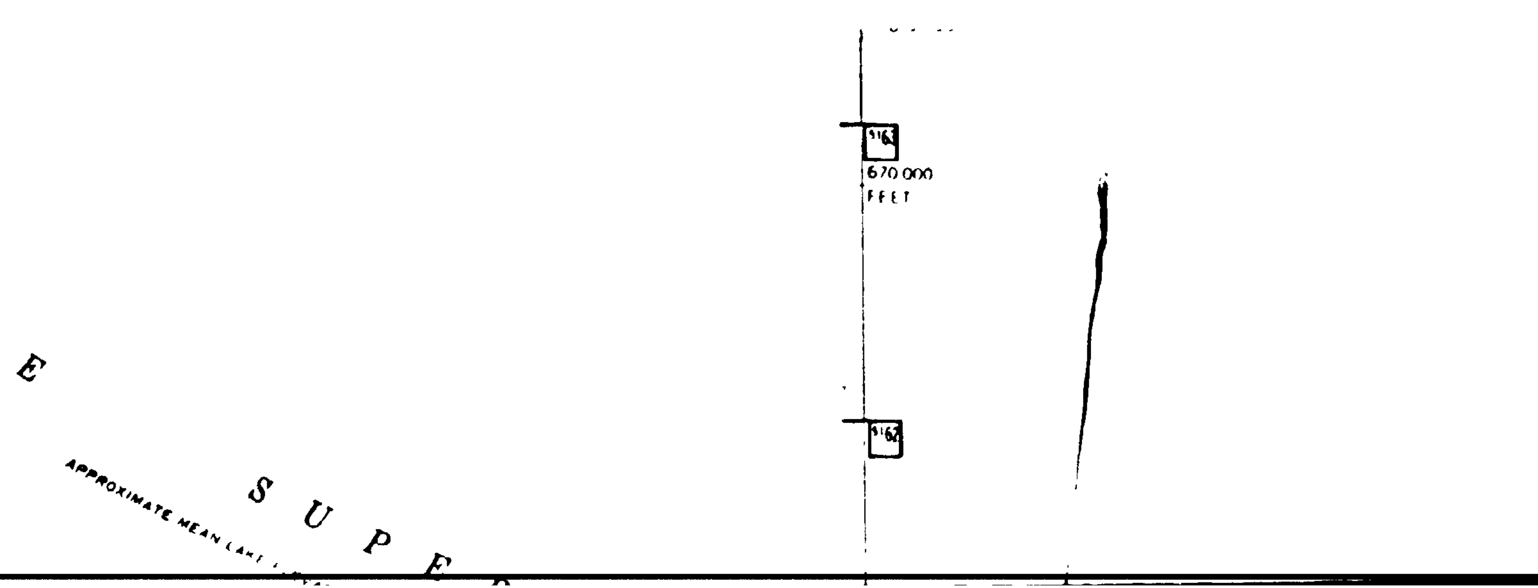

RIVER
STATE FOREST
29
28
27
M A R Q U E T T E
Nash
Nash Lake
Bismark

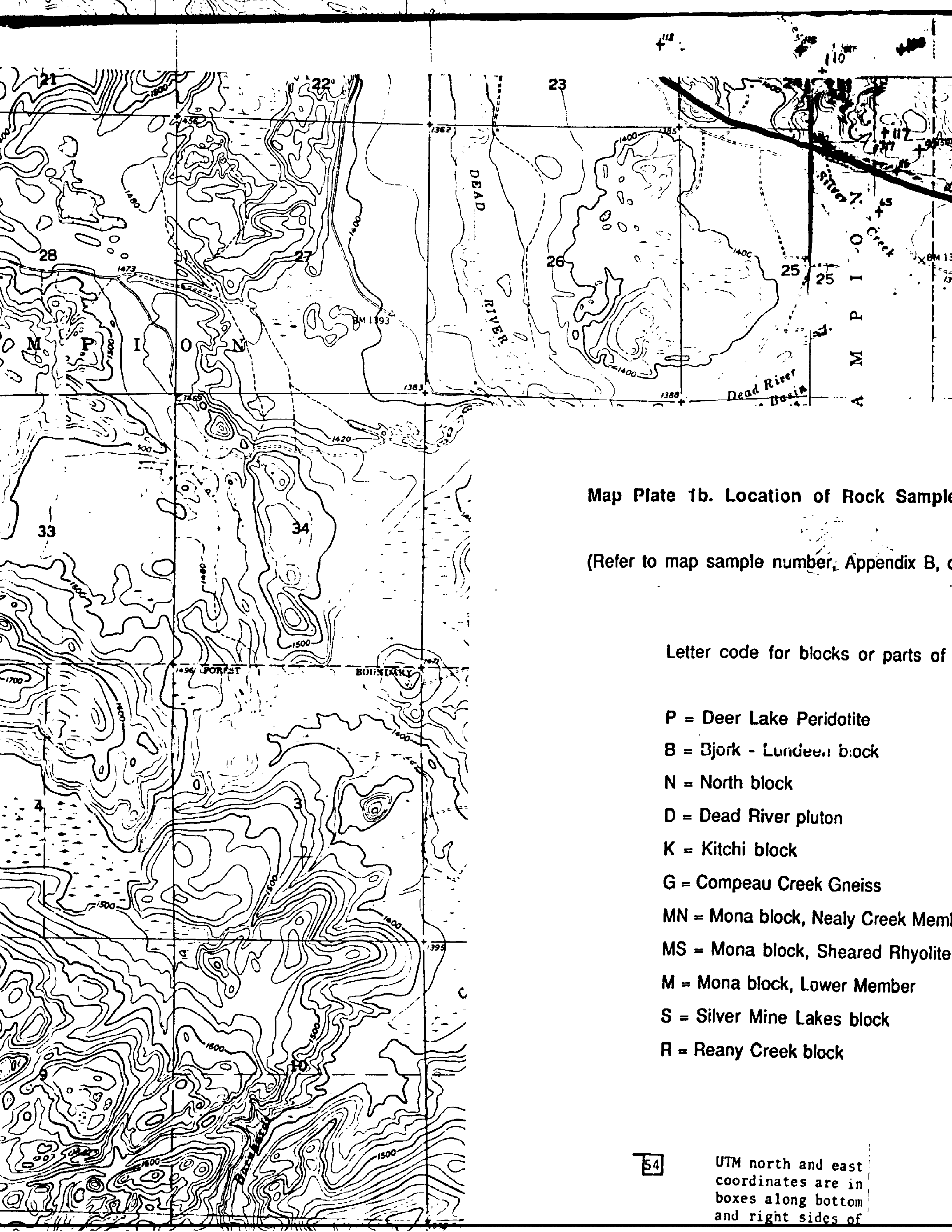
24
19
20
Freeman Landing
R 26 W
R 25 W
Gravel
Pit
Wetmore Landing
26
25
30
29


LAKE
Larus Island
700



Harlow Lake
19
20
800
700
R 26 W
R 25 W
Freeman Landing
Gravel Pit
Wetmore Landing
30
29
LAKE
Larus Island
L A K E


670 000
FEET
E
S U P E
APPROXIMATE MEAN LAKE



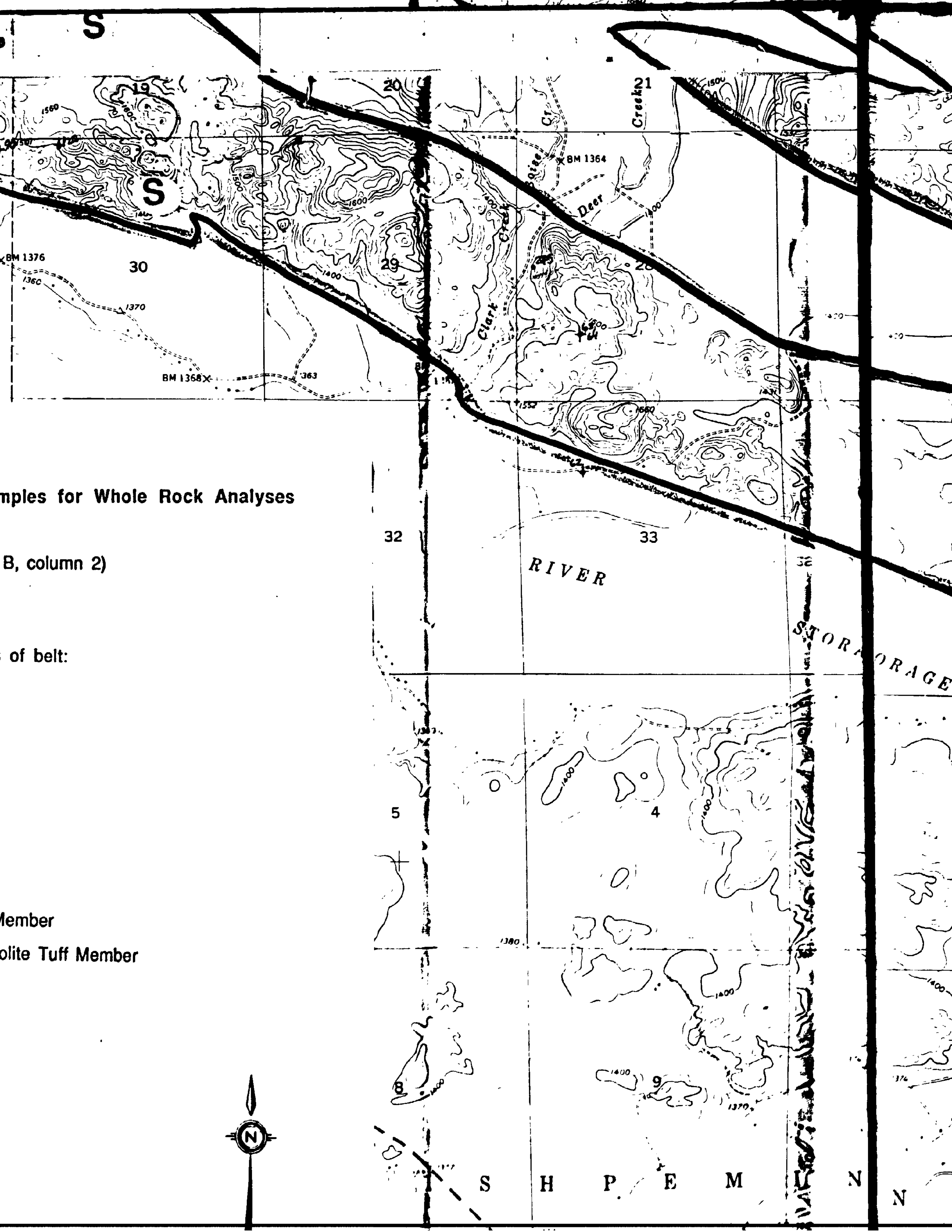
Map Plate 1b. Location of Rock Sample

(Refer to map sample number, Appendix B, c

Letter code for blocks or parts of

P = Deer Lake Peridotite
B = Bjork - Lundeen block
N = North block
D = Dead River pluton
K = Kitchi block
G = Compeau Creek Gneiss
MN = Mona block, Nealy Creek Meml
MS = Mona block, Sheared Rhyolite
M = Mona block, Lower Member
S = Silver Mine Lakes block
R = Reany Creek block

54 UTM north and east coordinates are in boxes along bottom and right sides of



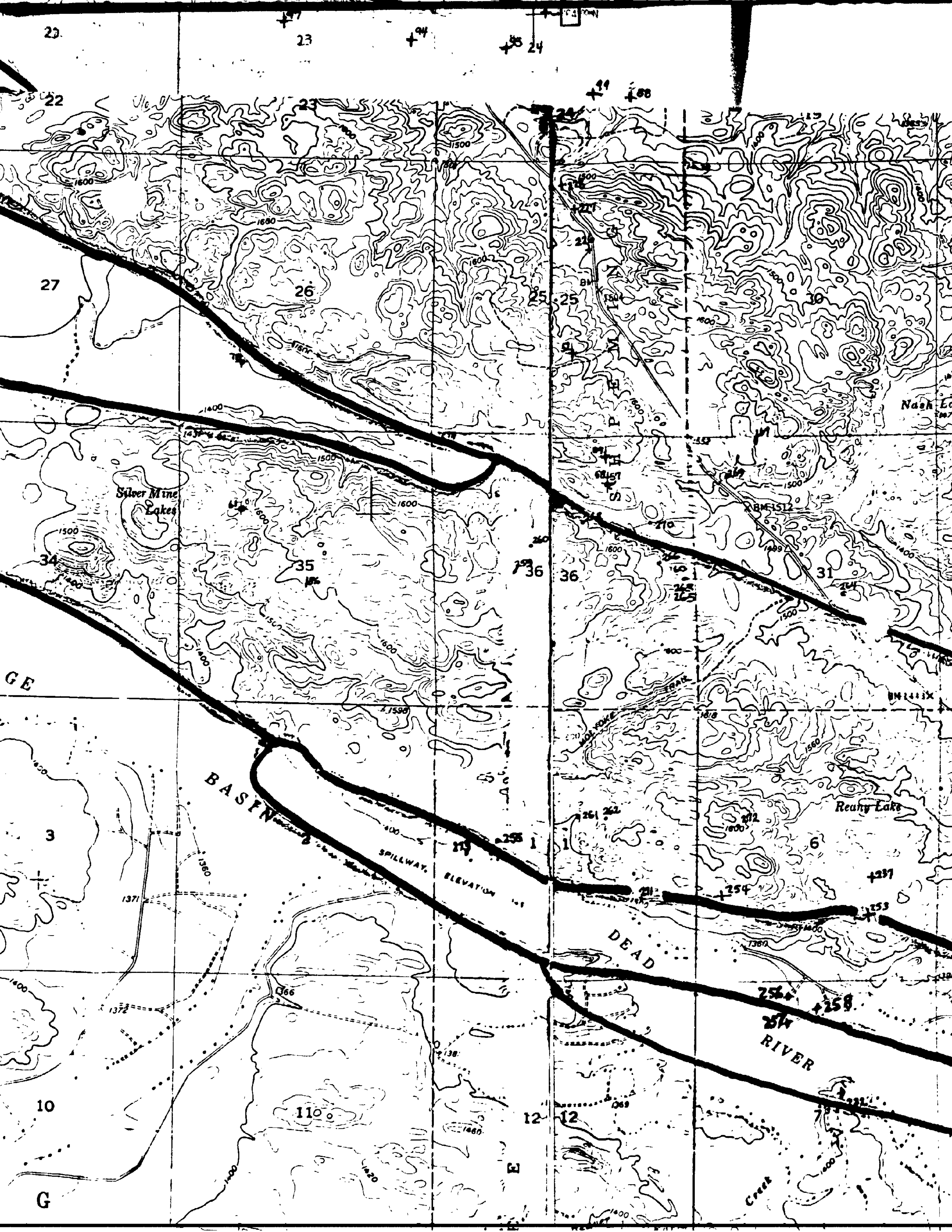
...mples for Whole Rock Analyses

... B, column 2)

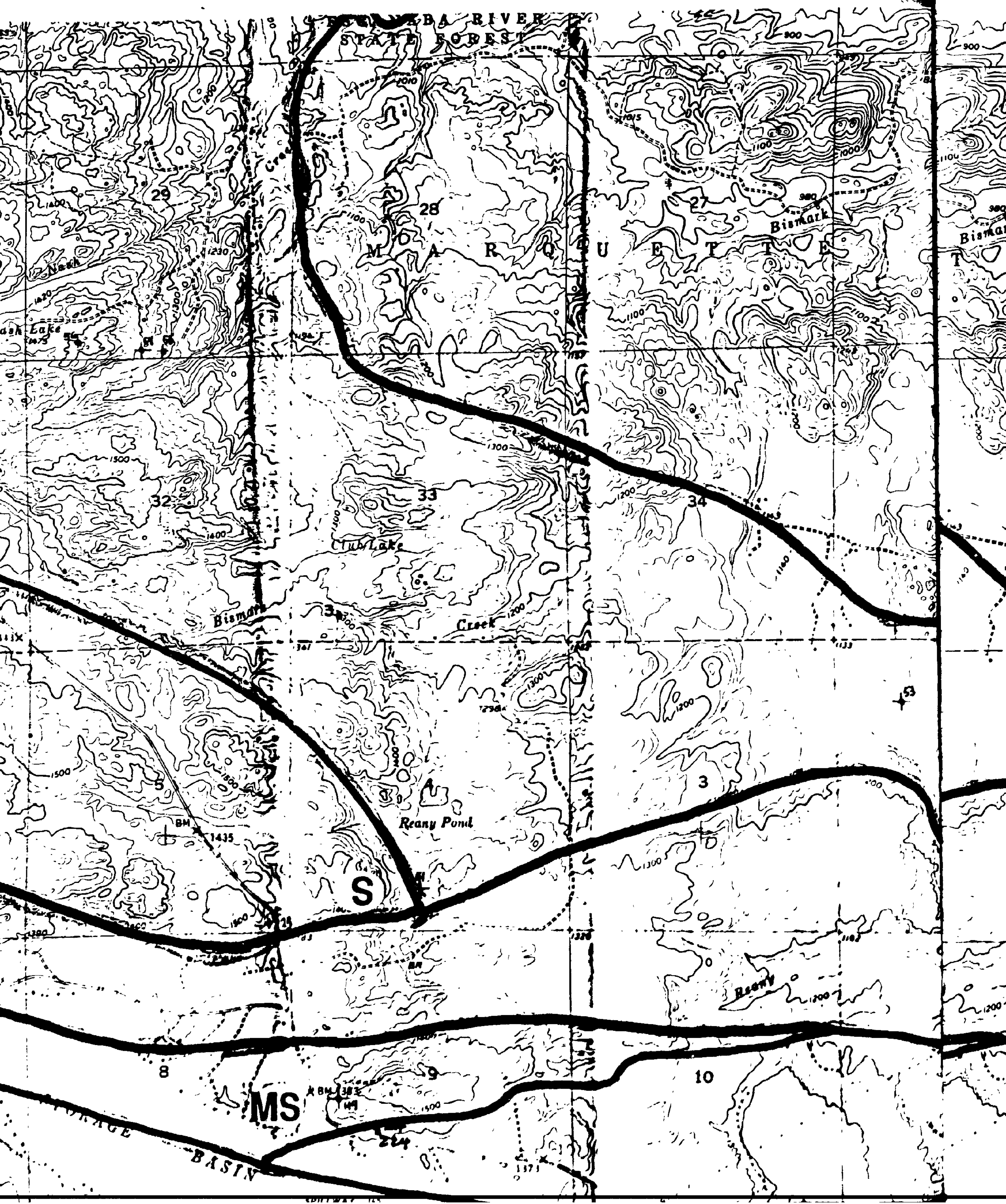
... of belt:

...Member

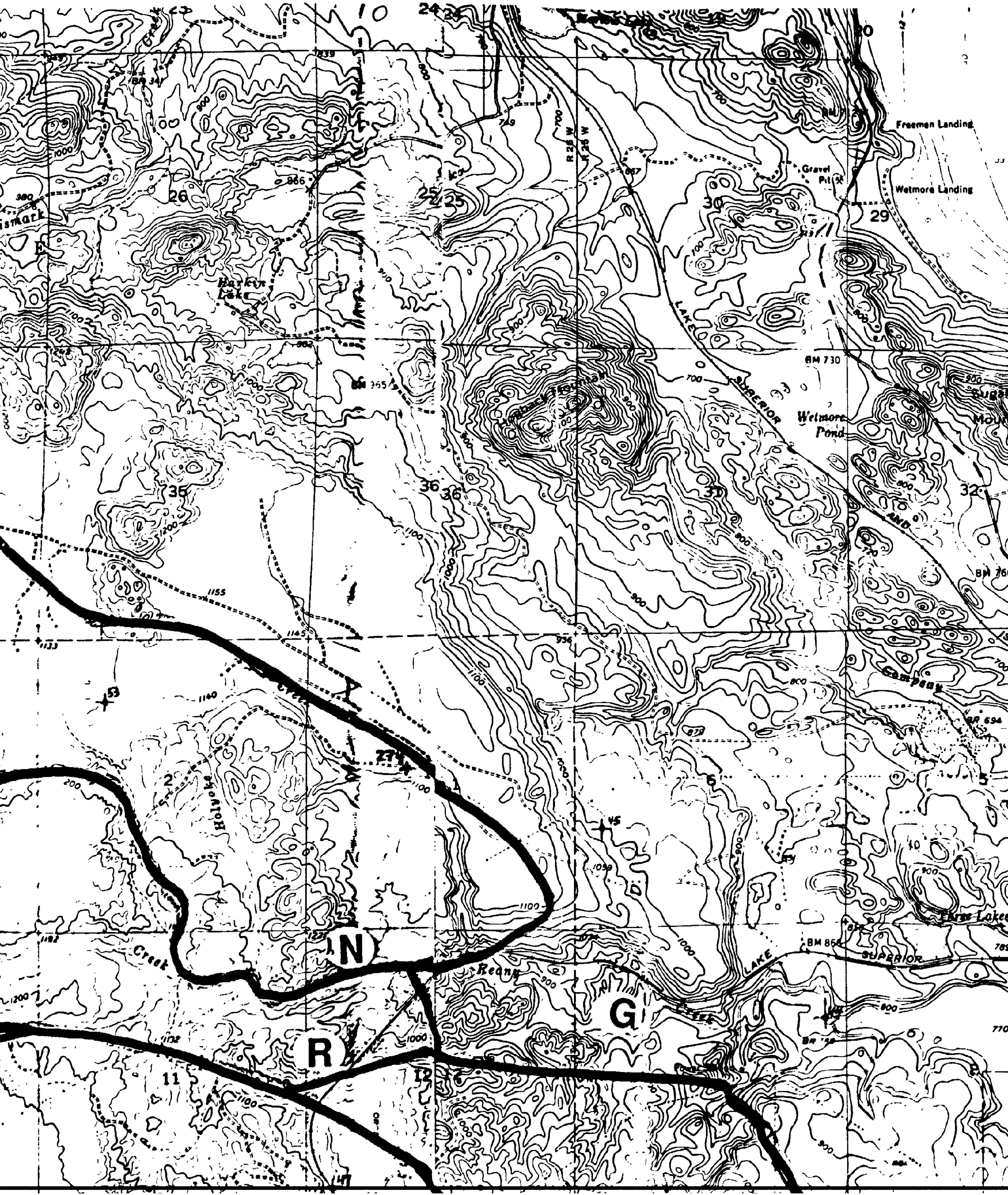
...olite Tuff Member

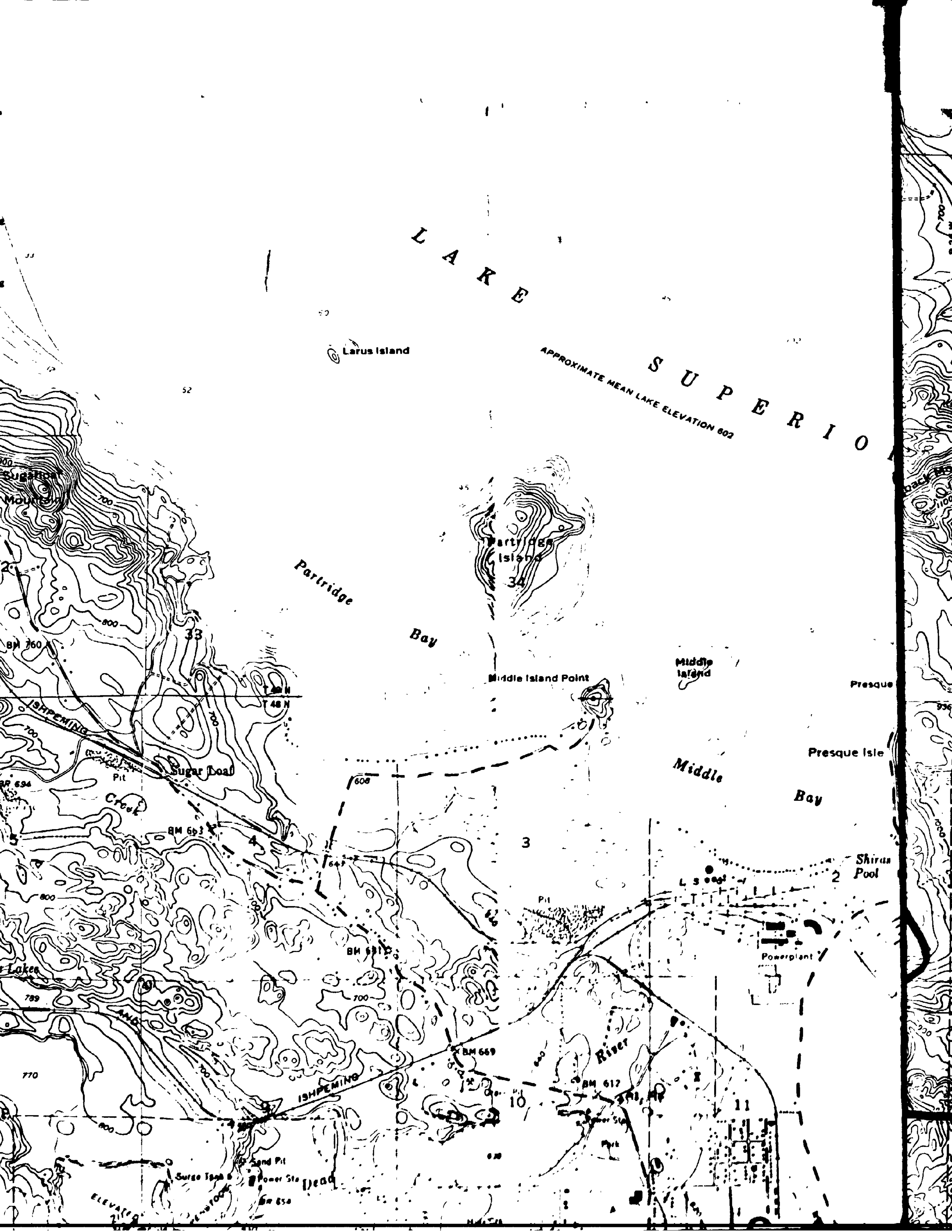


23
23
24
22
23
24
27
26
25
25
30
Nash La
Silver Mine Lakes
34
35
36
36
31
GE
BASIN
3
1
1
6
Reany Lake
SPILLWAY, ELEVATION
DEAD
RIVER
10
11
12
12
7
Creek
G



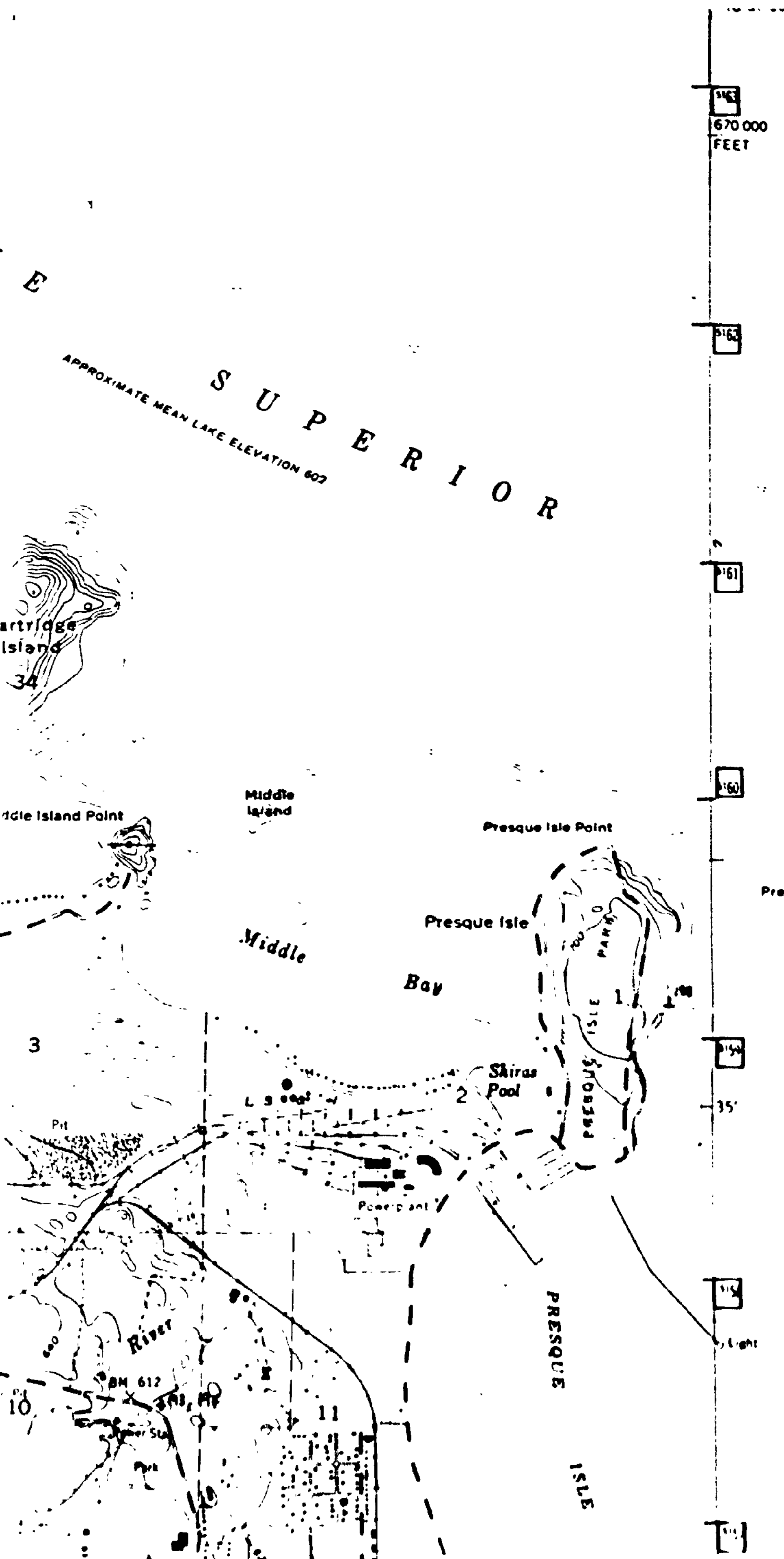
STATE FOREST
29
28
27
M A R Q U E T T E
Bismark
Nash
32
33
34
Club Lake
Bismark
Creek
5
3
Reany Pond
BM 1435
S
Reany
8
9
10
MS
BASIN


Freemen Landing
Wetmore Landing
Gravel Pit
Harlow Lake
Wetmore Pond
LAKE SUPERIOR AND
Company
BM 730
Holyoke
Creek
Reany
N
R
G
LAKE SUPERIOR
BM 864
Three Lakes

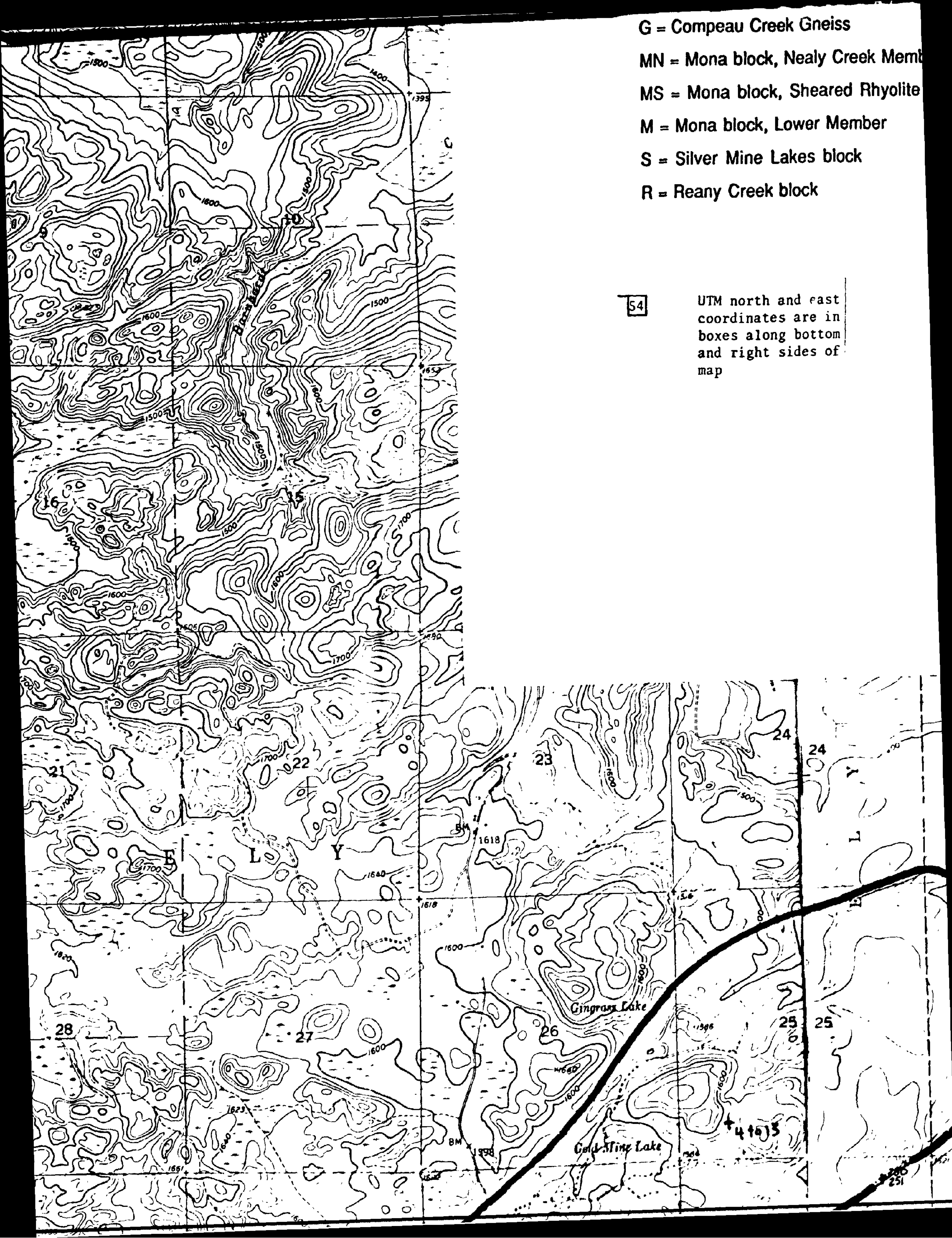


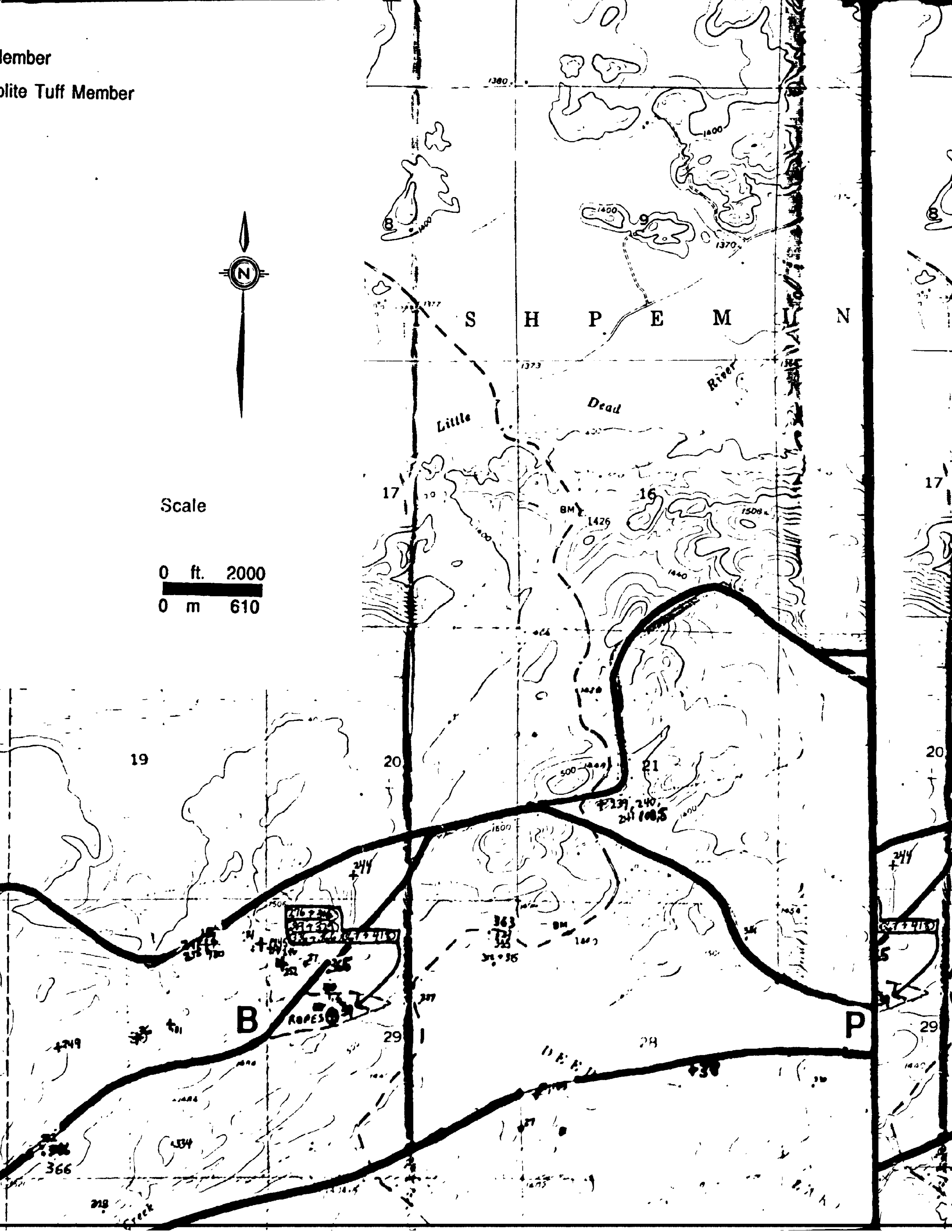
LAKE SUPERIOR
APPROXIMATE MEAN LAKE ELEVATION 602
Larus Island
Partridge Island
Partridge Bay
Middle Island Point
Middle Island
Middle Bay
Presque Isle
Shiras Pool
Sugarloaf Mountain
Sugar Loaf
Creek
ISHPEMING
River
Powerplant
Sand Pit
Surge Tank
Power Sta
Dead
Park
Pit
BM 760
BM 663
BM 669
BM 617
T 49 N
T 48 N

Freeman Landing
Gravel Pit
Wetmore Landing
29
LAKE
Larus Island
BM 730
LAKE
SUPERIOR
Wetmore Pond
Sugarloaf Mountain
32
Partridge Island
34
Partridge Bay
BM 760
33
Middle Isl
T 49 N
T 48 N
ISHPEMING
AND
Campeau
Sugar Loaf
Pit
Creek
BM 663
6
5
4
3
BM 681
Three Lakes
BM 866
LAKE
SUPERIOR
AND
ISHPEMING
BM 669
G
770
8
10
Sand Pit
Surge Tank
Power Sta
Dead
BM 654
ELEVATED

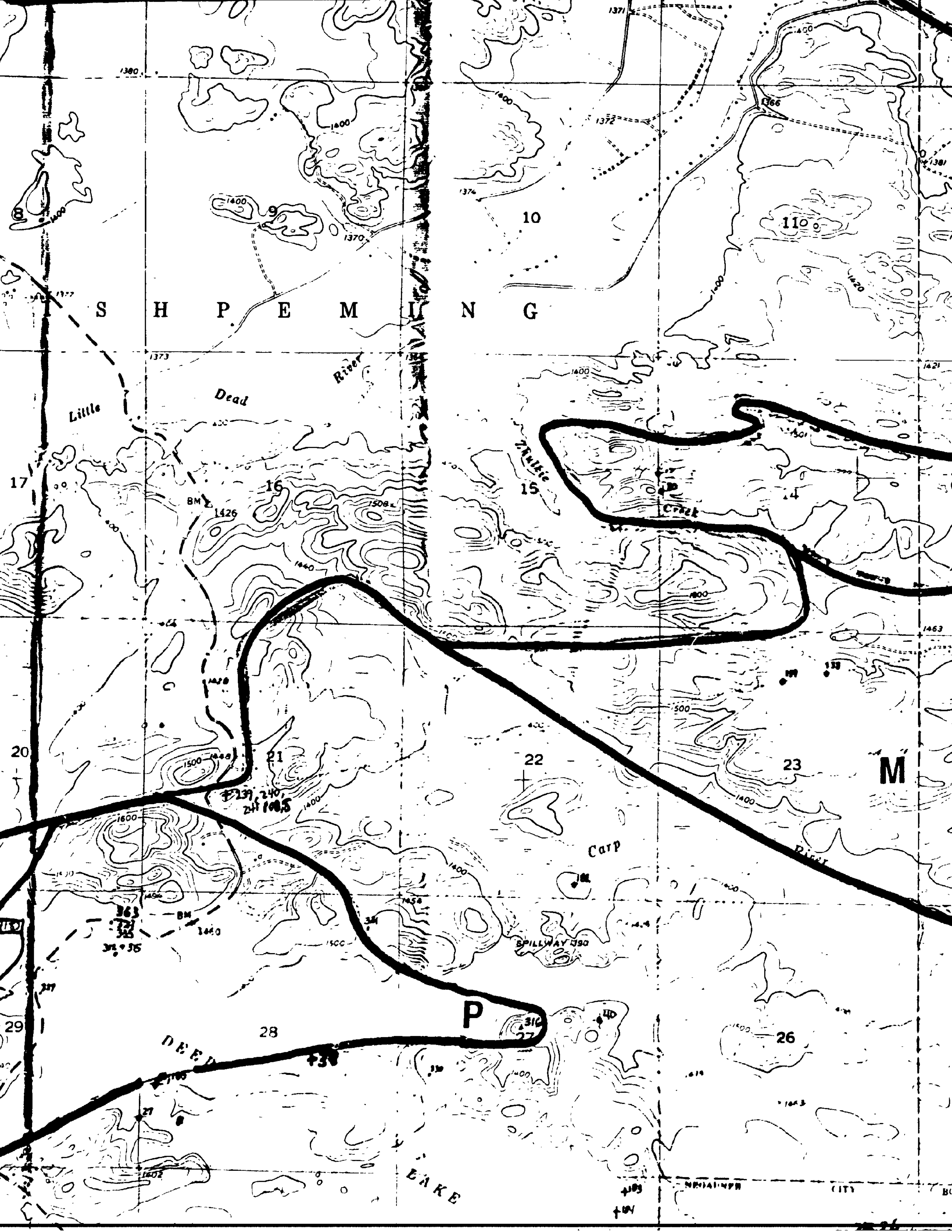

670 000
FEET
E
S U P E R I O R
APPROXIMATE MEAN LAKE ELEVATION 602
artridge
Island
34
Middle Island Point
Middle
Island
Presque Isle Point
Presque Isle Pt Rocks
Presque Isle
Middle
Bay
PRESQUE ISLE PARK
Shiras
Pool
3
2
1
35'
Pit
Powerplant
PRESQUE
ISLE
River
BM 612
10
11
Park
Light

Map Plate 1b

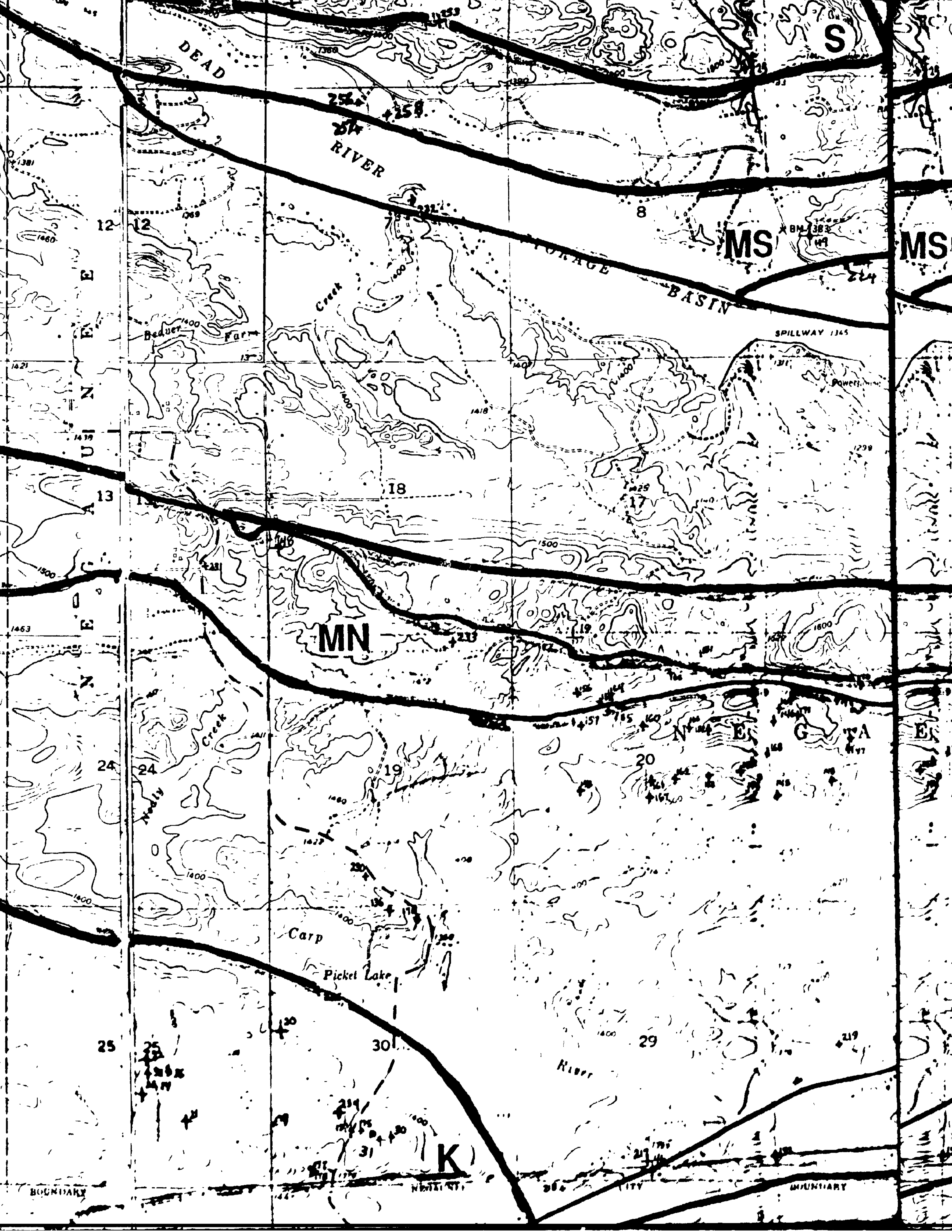

G = Compeau Creek Gneiss
MN = Mona block, Nealy Creek Memb
MS = Mona block, Sheared Rhyolite
M = Mona block, Lower Member
S = Silver Mine Lakes block
R = Reany Creek block
54
UTM north and east coordinates are in boxes along bottom and right sides of map
Gingrass Lake
Gold Mine Lake
E L Y
1618
1500
1600
1700
9
10
15
16
21
22
23
24
25
26
27
28
BM



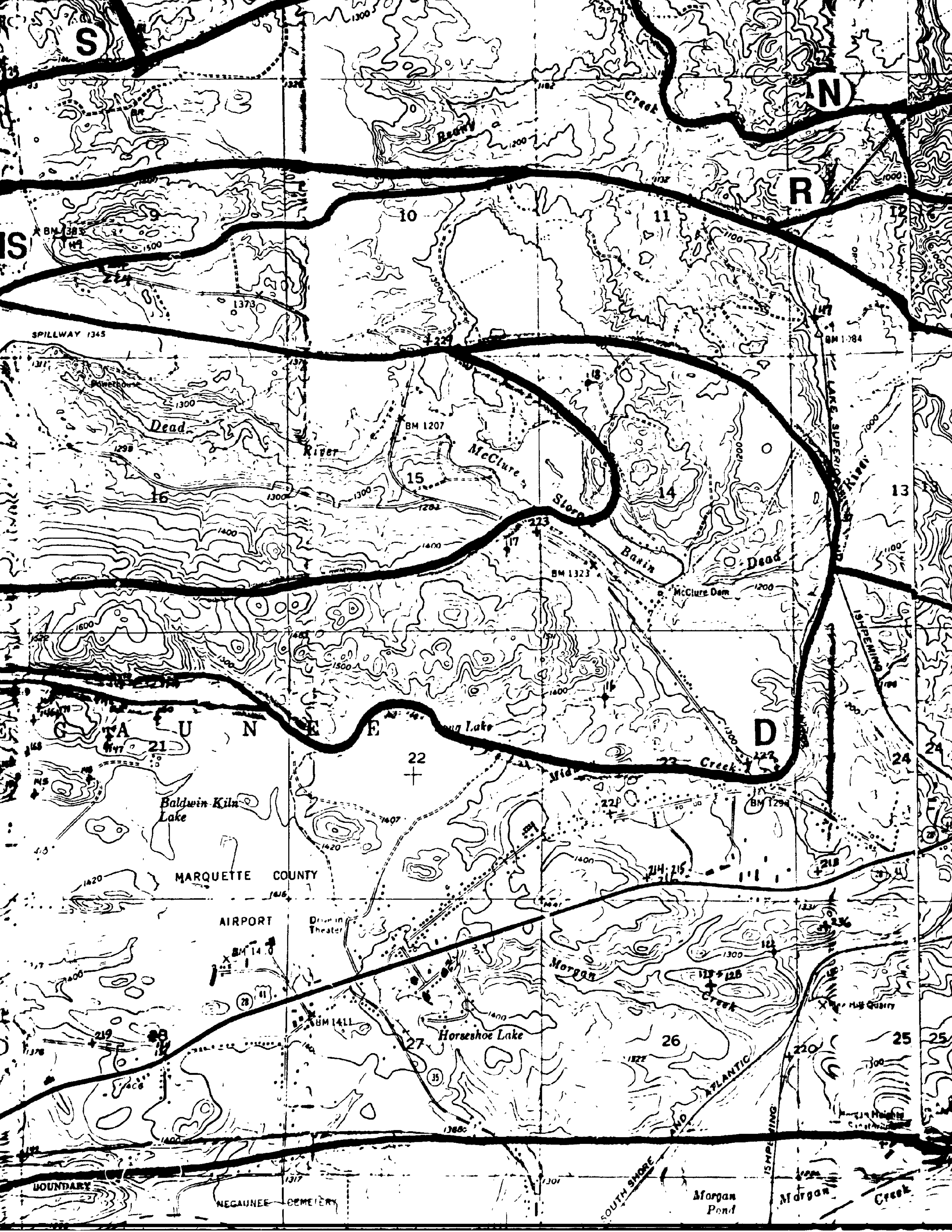
lember
plite Tuff Member
Scale
0 ft. 2000
0 m 610
I S H P E M I N
Little Dead River
ROPES
B
P
8
9
16
17
19
20
21
28
29

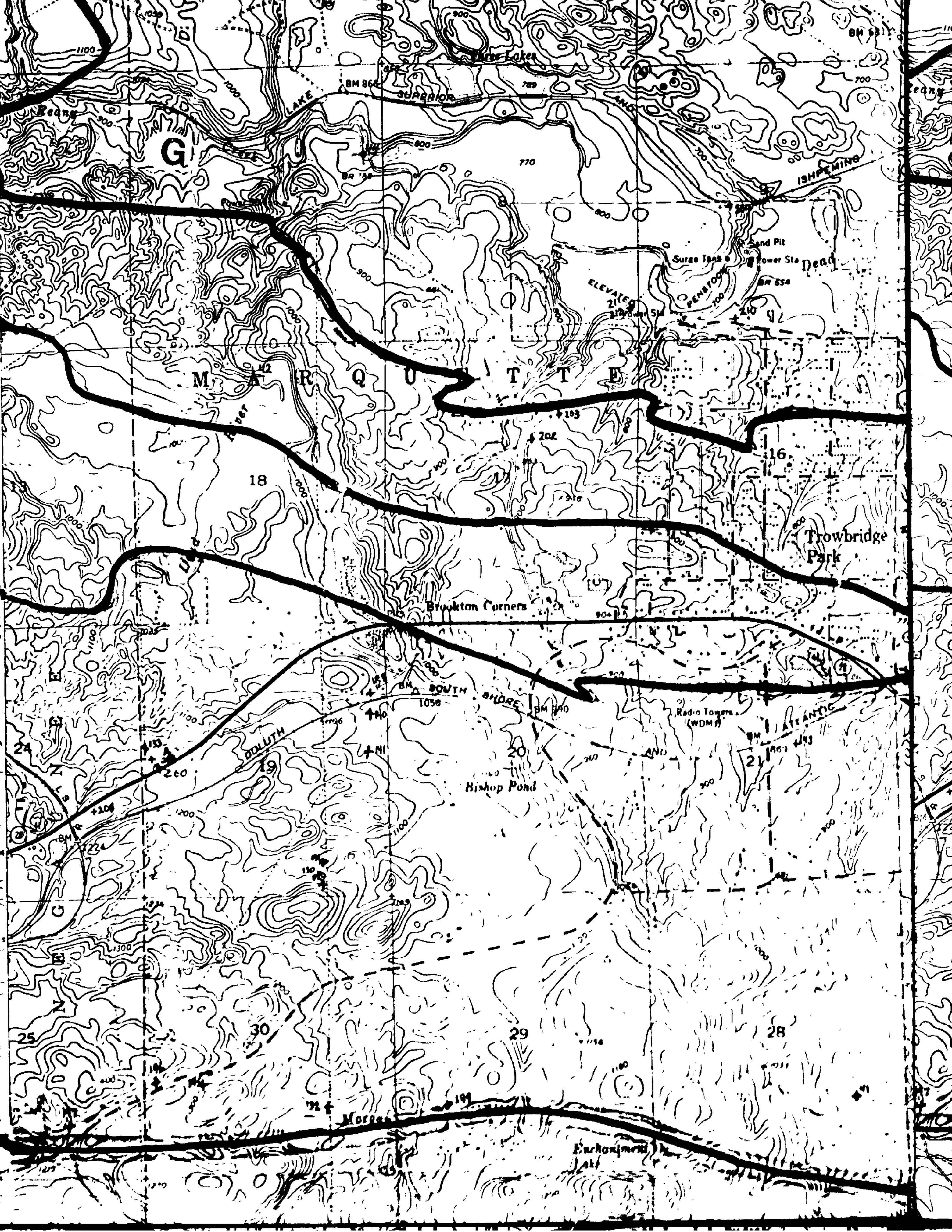


S H P E M I N G
Little
Dead
River
Creek
Carp
River
DEER
LAKE
SPILLWAY 1390
BM
P
M
8
9
10
11
14
15
16
17
20
21
22
23
26
27
28
29

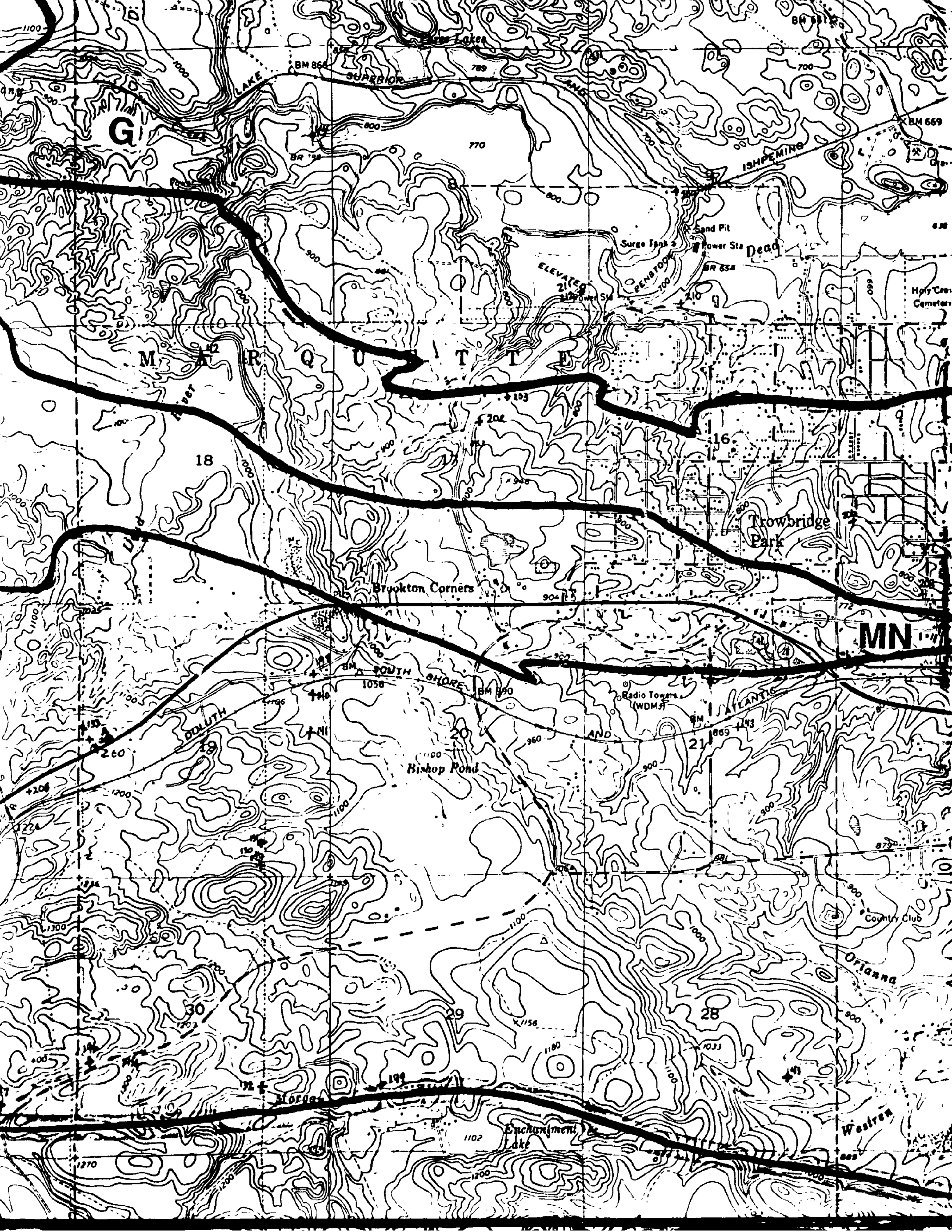


DEAD RIVER
STORAGE BASIN
SPILLWAY 1345
S
MS
MS
MN
K
Creek
Beaver Farm
Creek
Nodly Creek
Carp
Picket Lake
River
NEGAUNEE
BOUNDARY
CITY
BOUNDARY
12
13
18
17
8
19
20
24
25
30
29
31

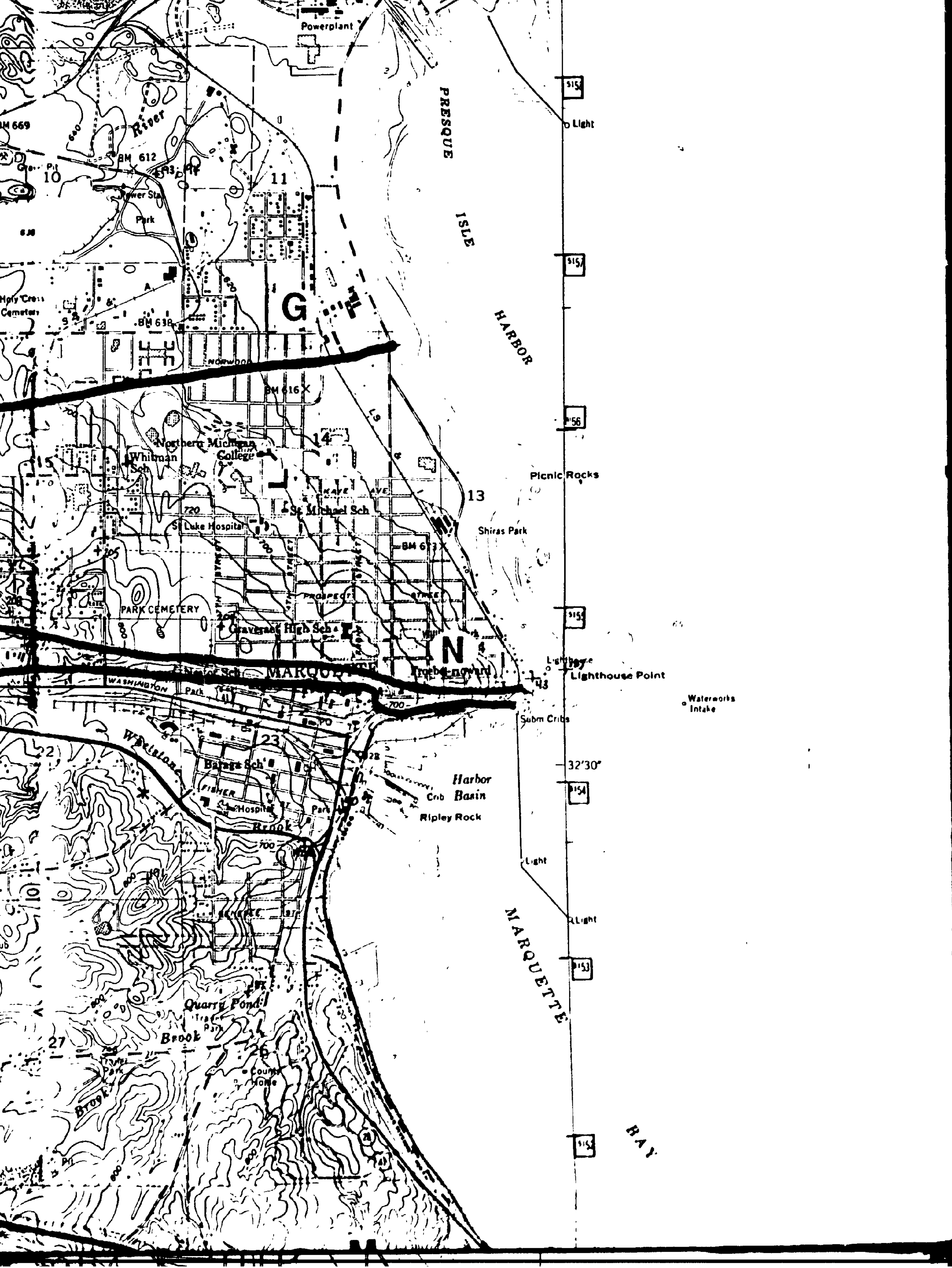

S
N
R
IS
D
9
10
11
12
13
14
15
16
21
22
24
25
26
27
Dead River
McClure Storage Basin
McClure Dam
Dead
SPILLWAY 1345
Powerhouse
BM 1207
BM 1323
BM 1084
BM 1298
BM 1411
LAKE SUPERIOR
ISHPEMING
Baldwin Kiln Lake
MARQUETTE COUNTY
AIRPORT
Drive in Theater
Morgan Creek
Horseshoe Lake
SOUTH SHORE AND ATLANTIC
NEGAUNEE CEMETERY
Morgan Pond
BOUNDARY
Creek



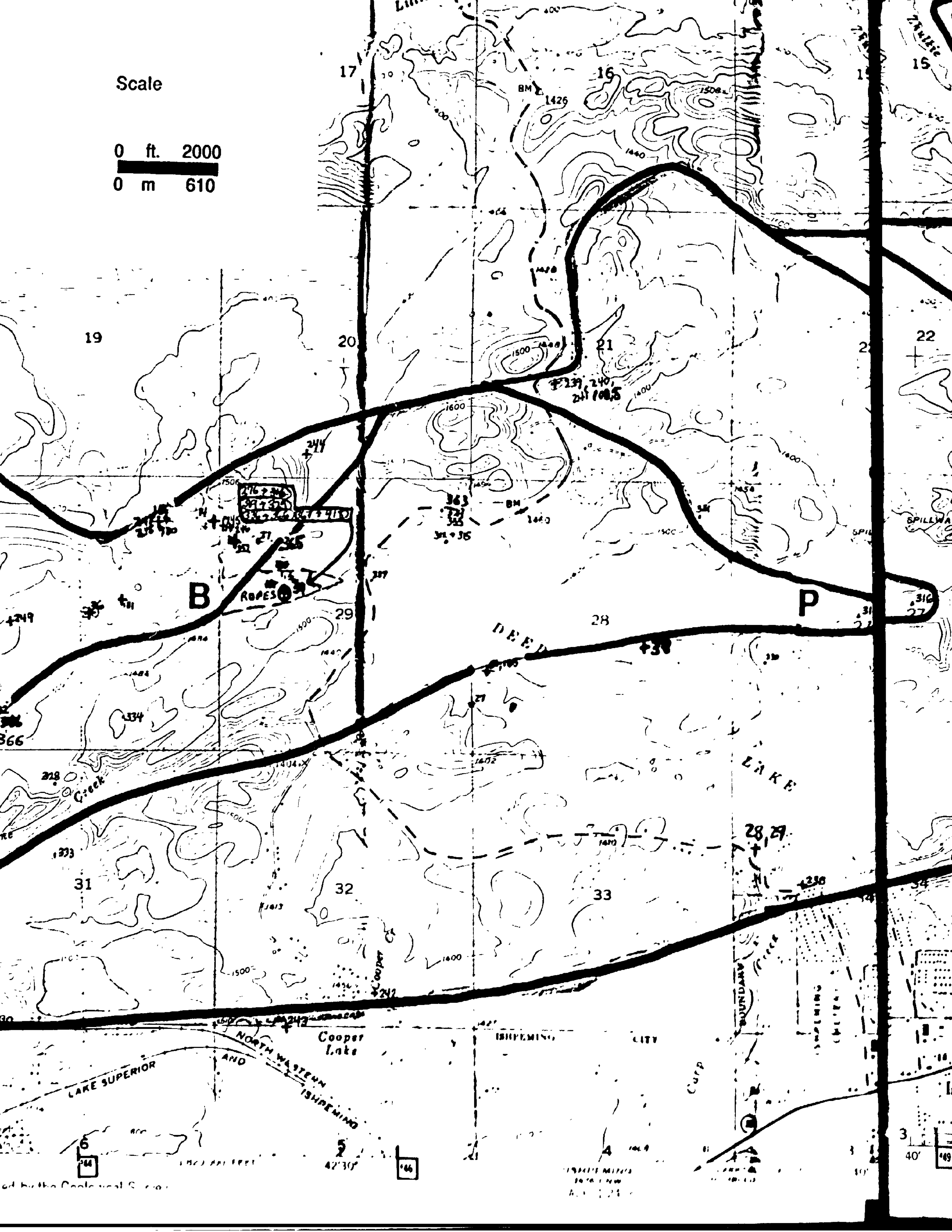
Three Lakes
SUPERIOR
LAKE
G
770
ISHPEMING
Sand Pit
Surge Tank
Power Sta
Dead
ELEVATED
PENSTOCK
M A R Q U E T T E
18
16
Trowbridge
Park
Brookton Corners
SOUTH SHORE
DULUTH
ATLANTIC
Radio Towers
(WDMJ)
Bishop Pond
19
20
21
24
25
30
29
28
Embankment

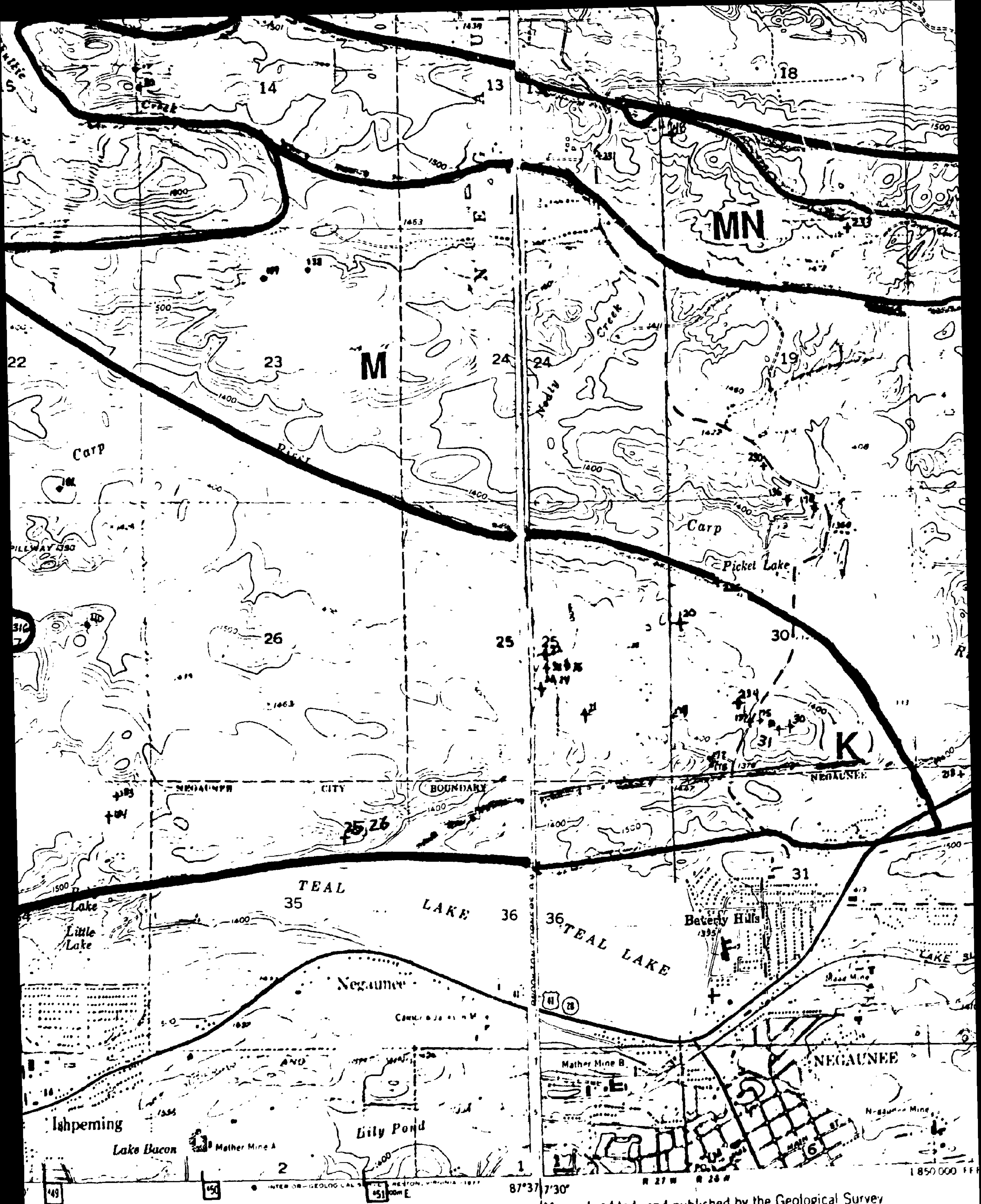


G
SUPERIOR
LAKE
ISHPEMING
BM 866
BM 669
770
Sand Pit
Surge Tank
Power Sta
ELEVATED
PENSTOCK
8
16
17
18
Trowbridge
Park
Brookton Corners
MN
SOUTH SHORE
DULUTH
AND
ATLANTIC
BM 890
1050
Radio Towers
(WDMJ)
19
20
21
Bishop Pond
Country Club
Orianna
30
29
28
Enchantment
Lake
1102

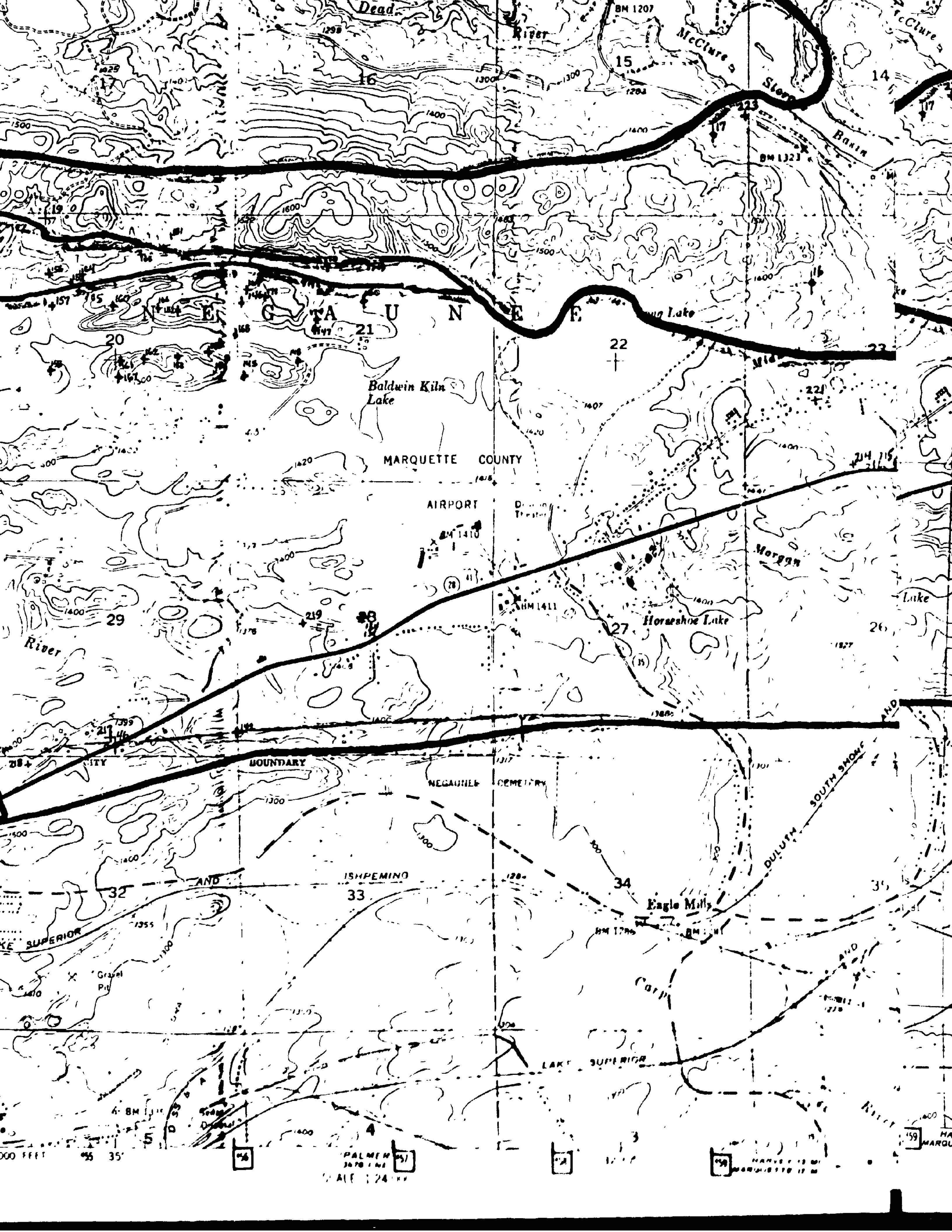

Powerplant
PRESQUE
ISLE
HARBOR
Light
BM 669
BM 612
10
11
Park
Holy Cross Cemetery
BM 638
G
NORWOOD
BM 616
14
Northern Michigan College
Whitman Sch
St Michael Sch
St Luke Hospital
Picnic Rocks
13
Shiras Park
PARK CEMETERY
Graveraet High Sch
N
MARQUETTE
WASHINGTON
Lighthouse Point
Waterworks Intake
Subm Cribs
23
22
Baraga Sch
FISHER
Hospital
Harbor Basin
Crib
Ripley Rock
32′30″
Light
MARQUETTE
BAY
Quarry Pond
Brook
27
26
County Home

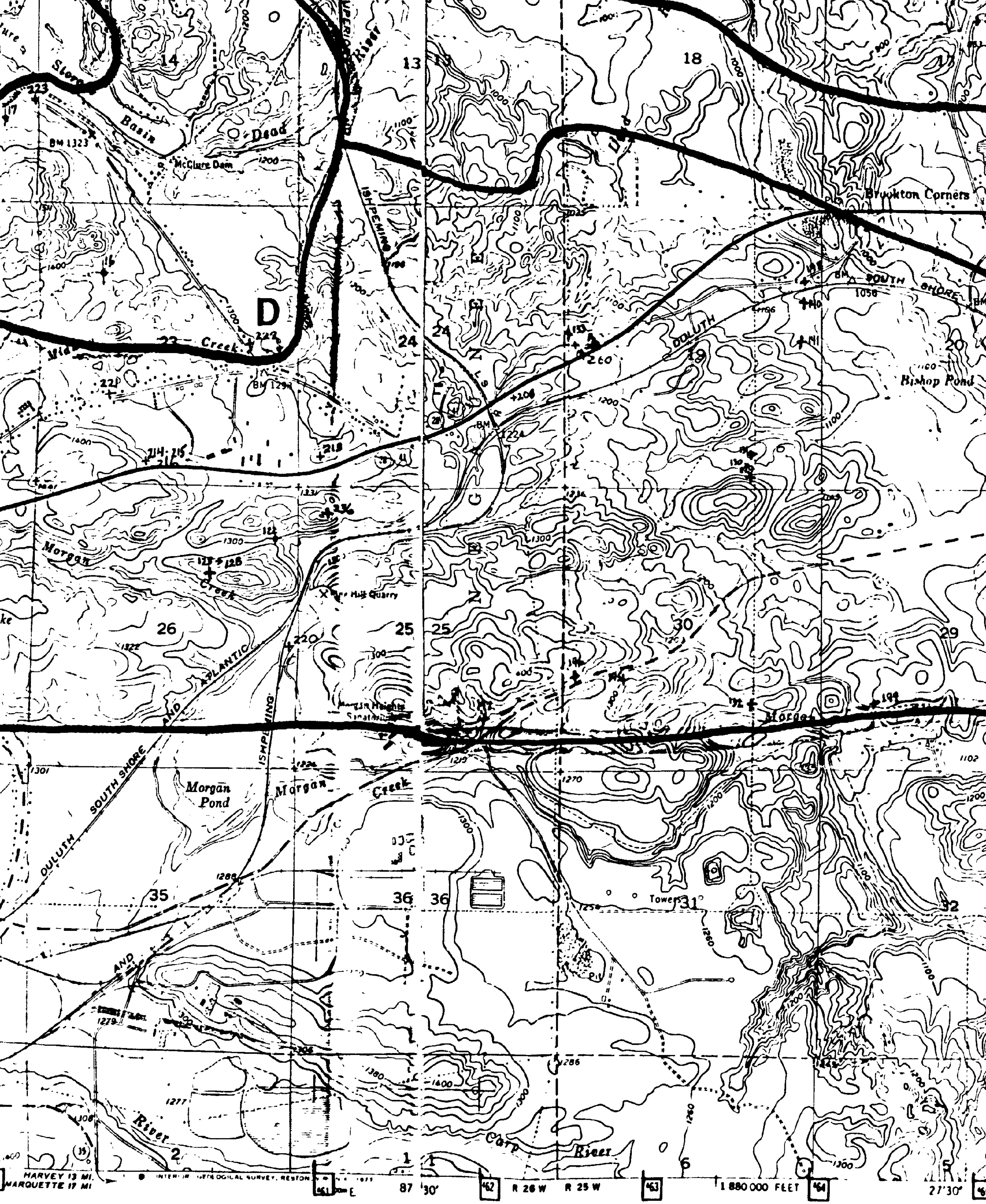

Gingrass Lake
Gold Mine Lake
Michigan Gold Mine
Gold Mine Creek
Gold Mine
CHICAGO NORTH WESTERN
CHICAGO
LAKE SUPERIOR AND ISHPEMING
ABANDONED
Chase Mine
Barnes and Hecker Mine
North Lake
Dexter Mine
Gravel Pit
Morris Mine
0.6 MI. TO U.S. 41
47'30"
GREENWOOD 1.2 MI
INTERIOR-GEOLOGICAL SURVEY, WASHINGTON D C
87°15'
R 28 W
R 27 W


Scale
0 ft. 2000
0 m 610
B
P
ROPES
DEER LAKE
Creek
Cooper Cr.
Cooper Lake
ISHPEMING
CITY
BOUNDARY Creek
LAKE SUPERIOR
AND
NORTH WESTERN
ISHPEMING
SPILLWAY
17
16
15
19
20
21
22
28
29
31
32
33
34
6
5
4
3

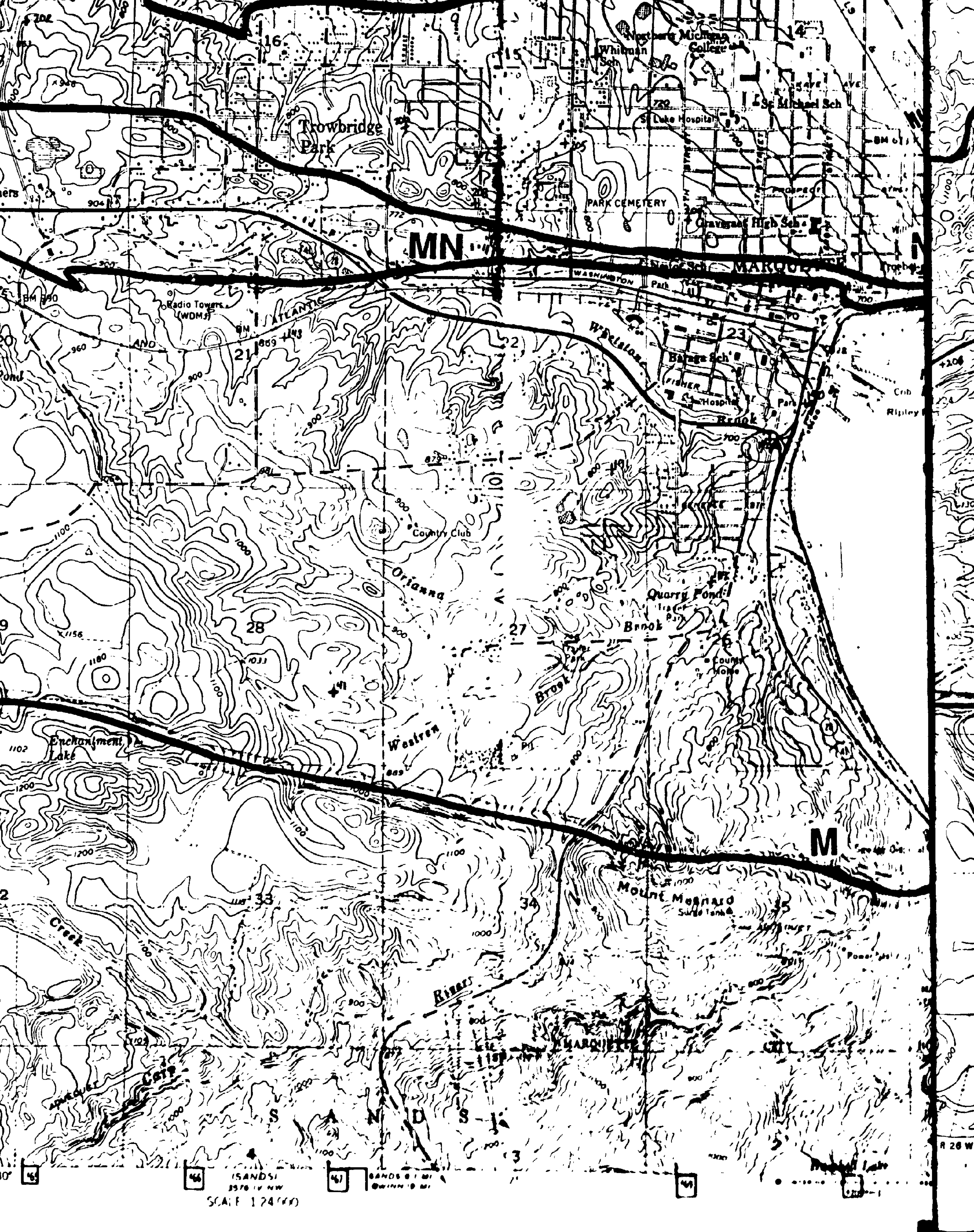


Mapped, edited, and published by the Geological Survey


Dead
River
McClure
Storage
Basin
N E G A U N E E
Baldwin Kiln Lake
MARQUETTE COUNTY
AIRPORT
Morgan
Horseshoe Lake
River
BOUNDARY
NEGAUNEE CEMETERY
ISHPEMING
AND
SUPERIOR
DULUTH SOUTH SHORE
Eagle Mills
Carp
LAKE SUPERIOR
River
Gravel Pit
BM 1207
BM 1323
BM 1410
BM 1411
15
16
17
14
20
21
22
29
27
26
32
33
34
4
5

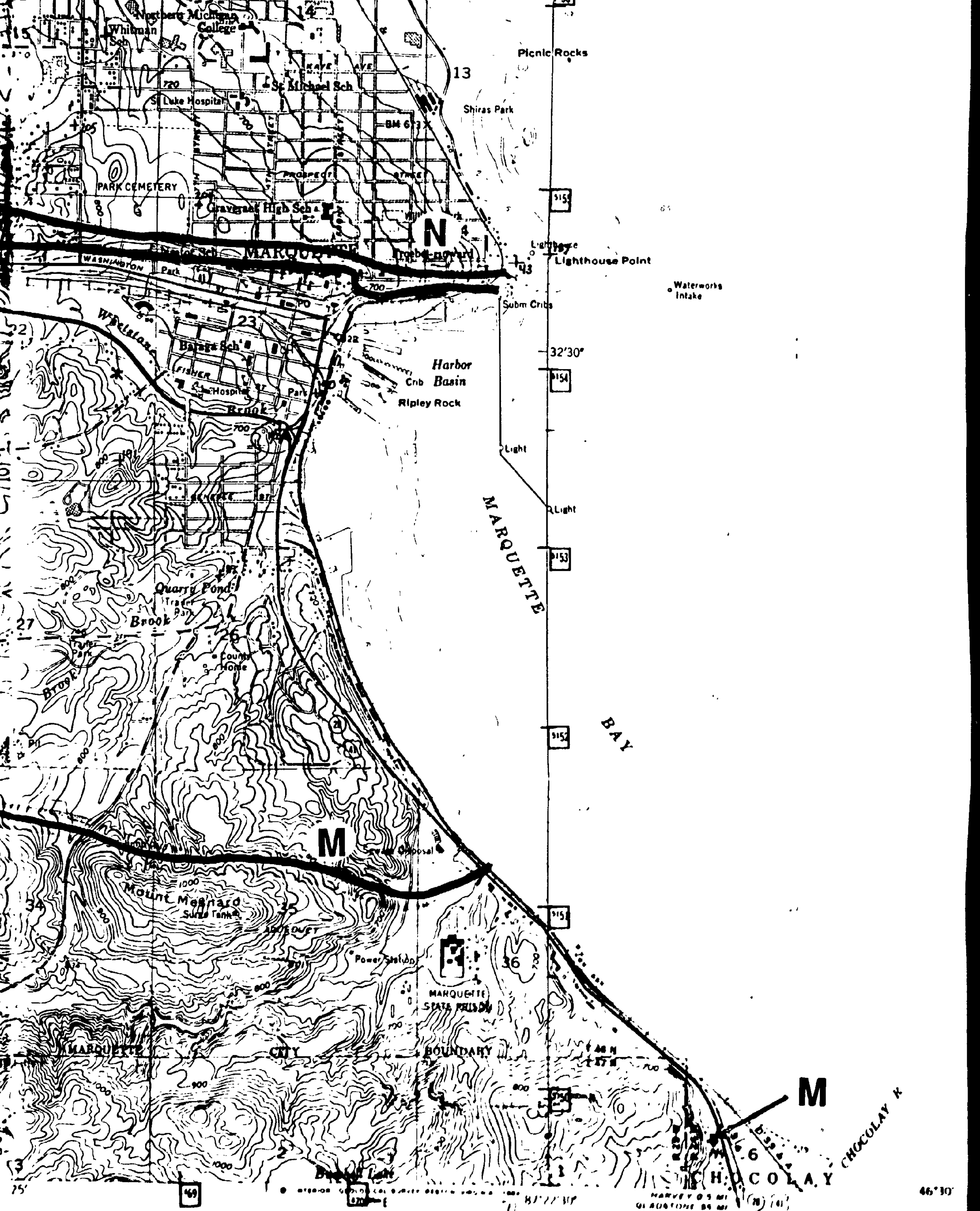


D
Storm
Basin
Dead
McClure Dam
BM 1323
ISHPEMING
Brookton Corners
SOUTH SHORE
DULUTH
Bishop Pond
Creek
Morgan
Creek
Morgan Heights Sanatorium
Morgan Pond
Morgan
Creek
DULUTH
SOUTH SHORE
AND
ATLANTIC
ISHPEMING
Tower
River
Carp
River
14
13
13
18
23
24
24
19
20
26
25
25
30
29
35
36
36
31
32
2
1
1
6
5
HARVEY 13 MI.
MARQUETTE 17 MI
87°30′
R 26 W
R 25 W
1 880 000 FEET
27′30″



Trowbridge Park
Northern Michigan College
Whitman Sch
St Michael Sch
St Luke Hospital
PARK CEMETERY
Graveraet High Sch
MN
MARQUETTE
WASHINGTON
Radio Towers (WDMJ)
ATLANTIC
Whetstone
Baraga Sch
FISHER
Hospital
Brook
Country Club
Orianna
Quarry Pond
Brook
Brook
Western
Enchantment Lake
Creek
Mount Marquette
M
Carp
S A N D S
MARQUETTE
CITY
16
14
21
22
23
28
27
26
33
34
35
SCALE 1:24000

SCALE 1 24 000



Northern Michigan College
Whitman Sch
Picnic Rocks
13
St Michael Sch
St Luke Hospital
Shiras Park
PARK CEMETERY
Graveraet High Sch
N
MARQUETTE
Lighthouse Point
Waterworks Intake
Subm Cribs
23
Baraga Sch
32'30"
Harbor Basin
Crib
Ripley Rock
Hospital
Park
Brook
Light
Light
MARQUETTE
Quarry Pond
Trailer Park
Brook
27
26
County Home
Brook
BAY
M
Mount Mesnard
Surge Tank
34
Power Station
36
MARQUETTE STATE PRISON
MARQUETTE
CITY
BOUNDARY
M
CHOCOLAY R
CHOCOLAY
46°30'

Map Plate 2. GEOLOGIC MAP OF THE SOUTHWEST PART OF THE MARQUETTE GREENSTONE BELT

ST PART OF
BELT

erozoic

4. sedimentary rocks
   - b. graywacke
   - c. siltstone
   - d. slate
   - g. quartzite

Archean (Marquette Greenstone Belt)

11. veins
    - q = quartz
    - c = carbonate

6. intrusive rocks
   - c. tonalite
   - d. granodiorite

5. peridotite and related rocks
   - a. serpentinitic peridotite
     - c - carbonate rich
     - t - carbonate - talc rock
     - d - carbonate - quartz - chlorite rock

4. sedimentary rocks
   - b. graywacke

3. chemical sedimentary rocks
   - ao. banded quartz - magnetite iron formation
   - c. chert with clastic component

2. dacite, rhyodacite, and rhyolite; 1.5 andesite
   - a. flow
     - p - porphyritic
   - b. tuff
     - p - porphyritic
     - f - tuff breccia
     - l - lapilli tuff
     - m - sericite rich
     - s - siliceous, with quartz veins
   - c. hypabyssal sill or dike
     - p - porphyritic

1. basalt
   - a. flow
     - p - pillowed
     - v - variolitic
     - o - opi...ic
     - f - flow top breccia
     - g - glomerophyric
     - c - carbonate rich
     - m - sericite rich
   - b. tuff (may include schistose basalt)

Source: mapping and co

Refer to ind

Source: mapping and

Refer to i

Geologic contact

Shear Zone

Fault, with sense of offset

Outcrop

Strike and dip of foliation

Strike and dip of bedding

Bearing and plunge of linea

Younging direction:

bedding

basalt pillows

Core drill hole, vertical p

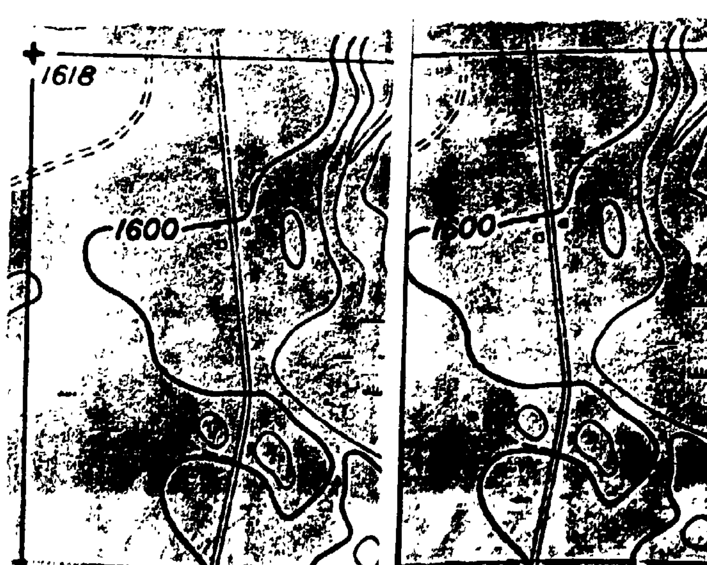
Shaft (may be minor)

Minor prospect

Projection to surface of g

Magnetic low within serp numbered locatic in Chapter 3.7.5

Geologic contact
Shear Zone
Fault, with sense of offse
Outcrop
Strike and dip of foliatio
Strike and dip of bedding
Bearing and plunge of lin
Younging direction:
bedding
basalt pillows
Core drill hole, vertical
Shaft (may be minor)
Minor prospect
Projection to surface of
Magnetic low within ser numbered locat in Chapter 3.7.



g and compilation by Callahan Mining Corporation
' to index for sources on Map plate 1a.

f offset if known

oliation

edding

e of lineation

N

ertical projection to surface

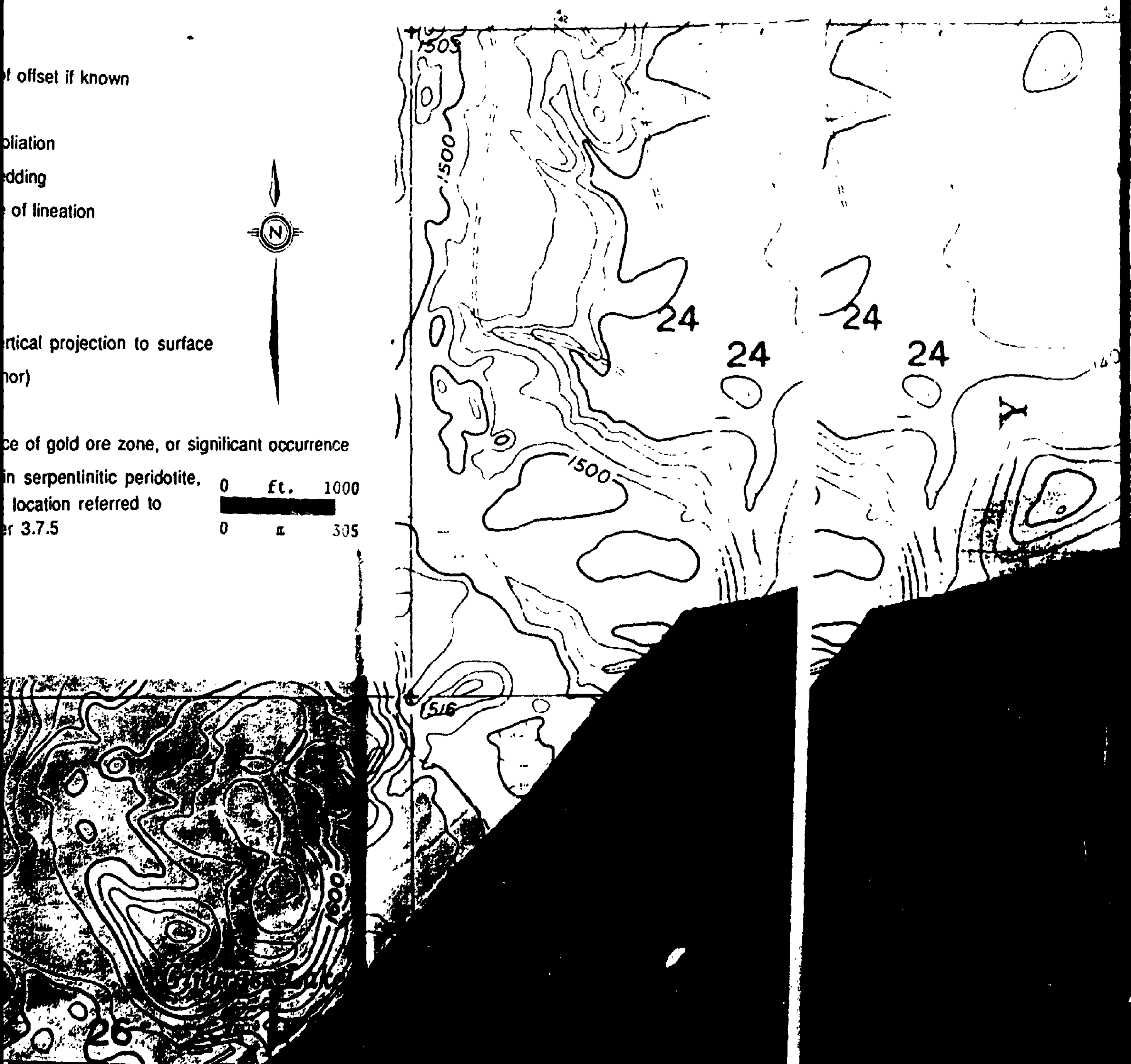
hor)

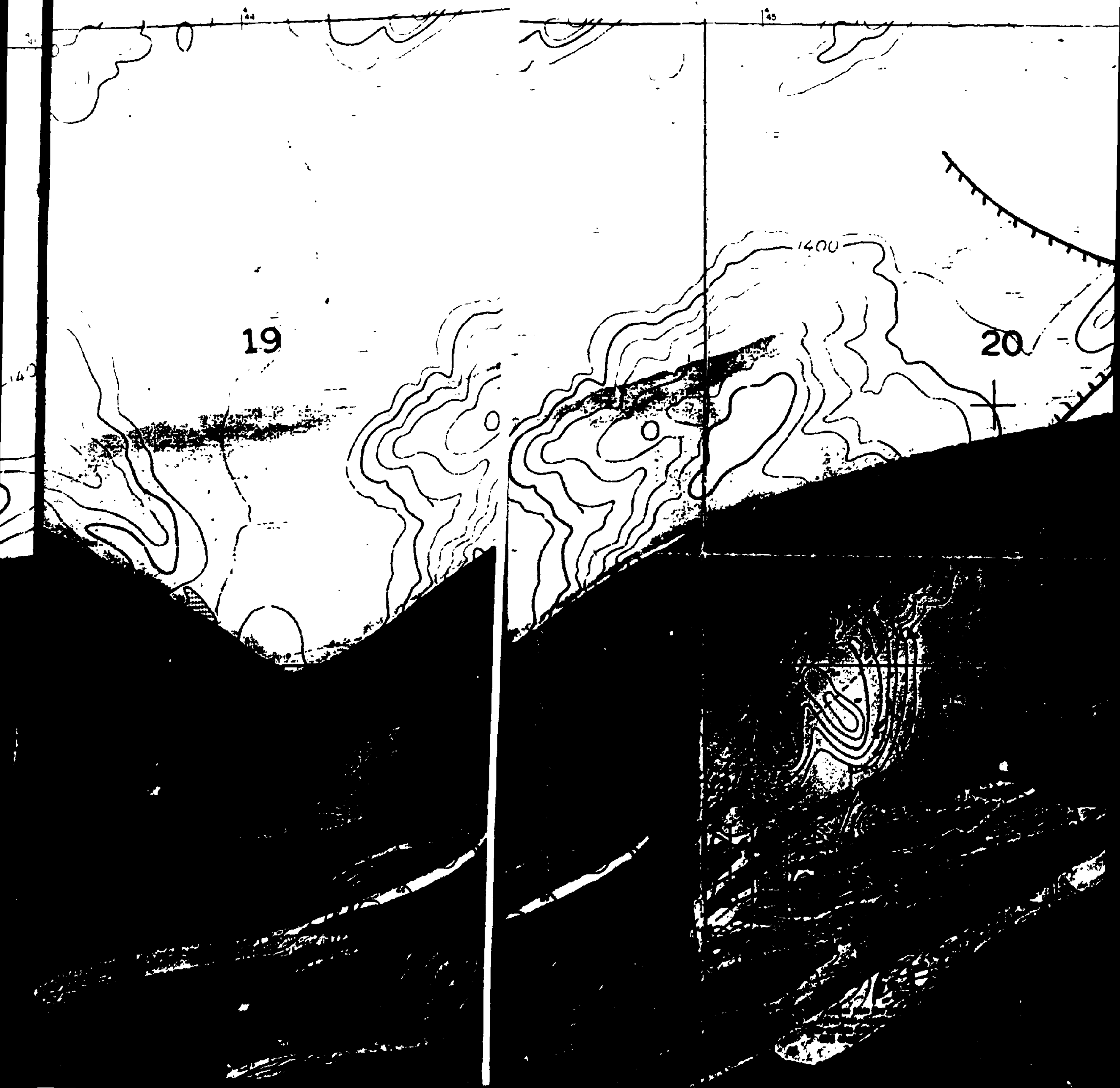
ce of gold ore zone, or significant occurrence

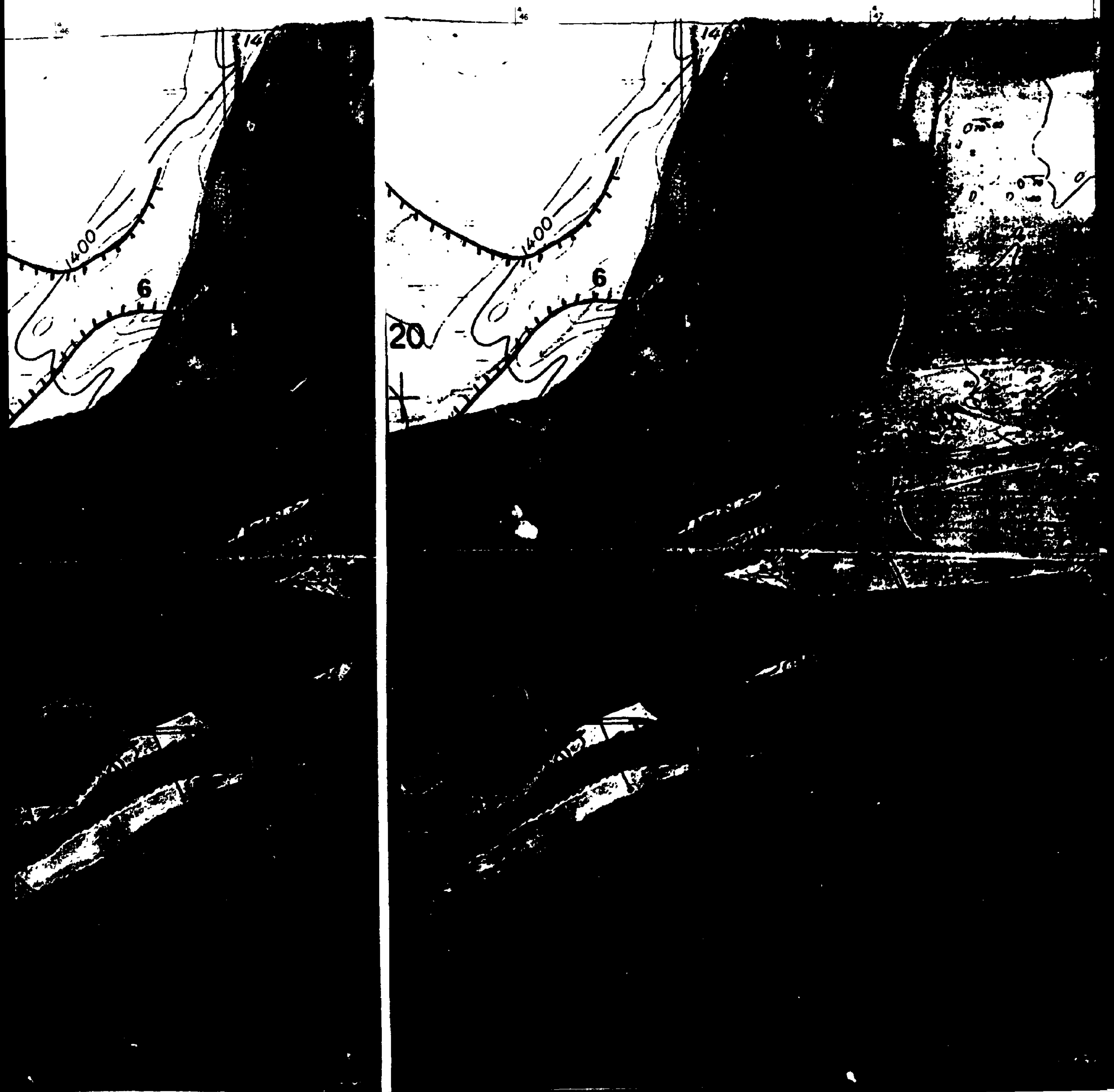
in serpentinitic peridotite,
location referred to
er 3.7.5

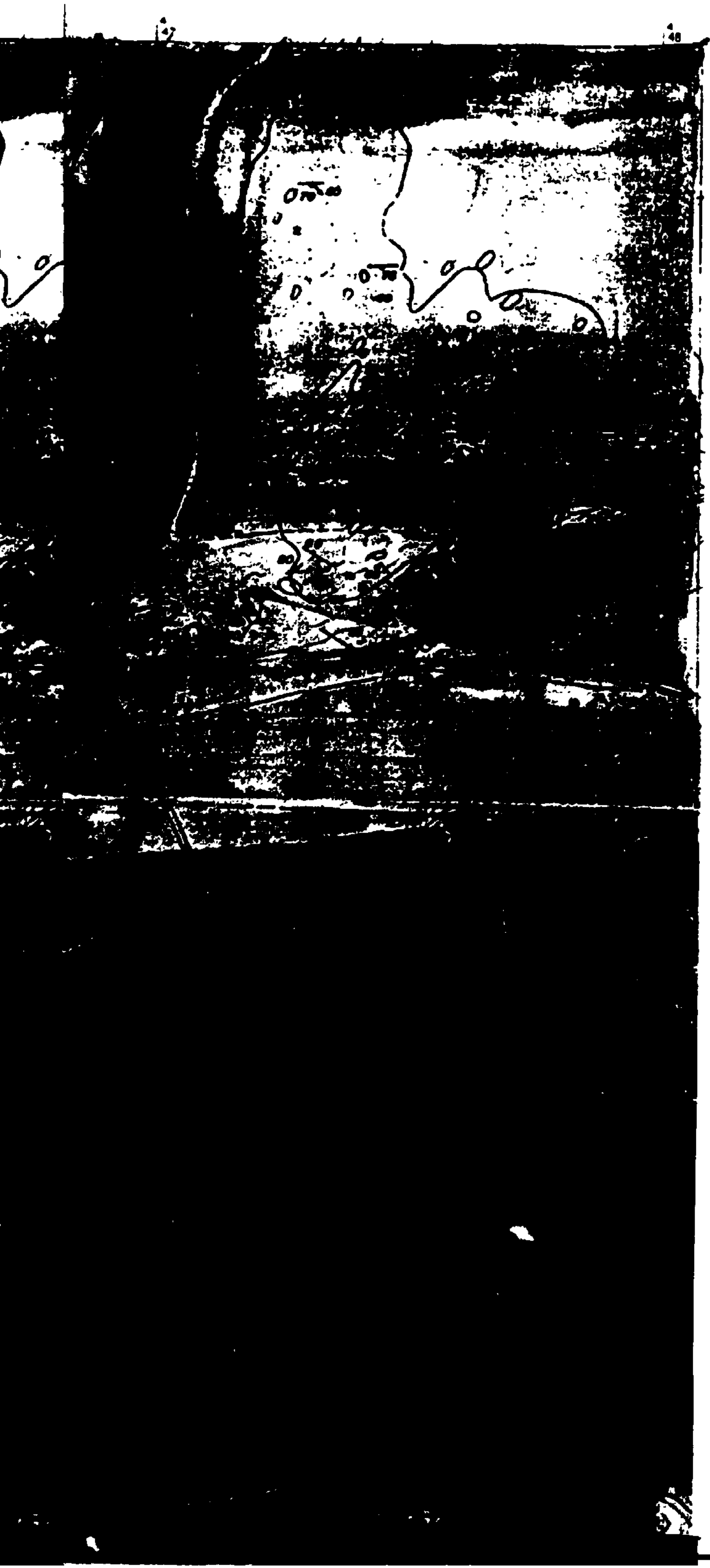
0 ft. 1000

0 m 305




19
20
1400


1400
6
1400
6
20



a. flow

p - porphyritic

b. tuff

p - porphyritic

f - tuff breccia

l - lapilli tuff

m - sericite rich

s - siliceous, with quartz veins

c. hypabyssal sill or dike

p - porphyritic

1. basalt

a. flow

p - pillowed

v - variolitic

o - ophitic

f - flow top breccia

g - glomerophyric

c - carbonate rich

m - sericite rich

b. tuff (may include schistose basalt)

f - tuff breccia

l - lapilli tuff

c - carbonate rich

m - sericite rich

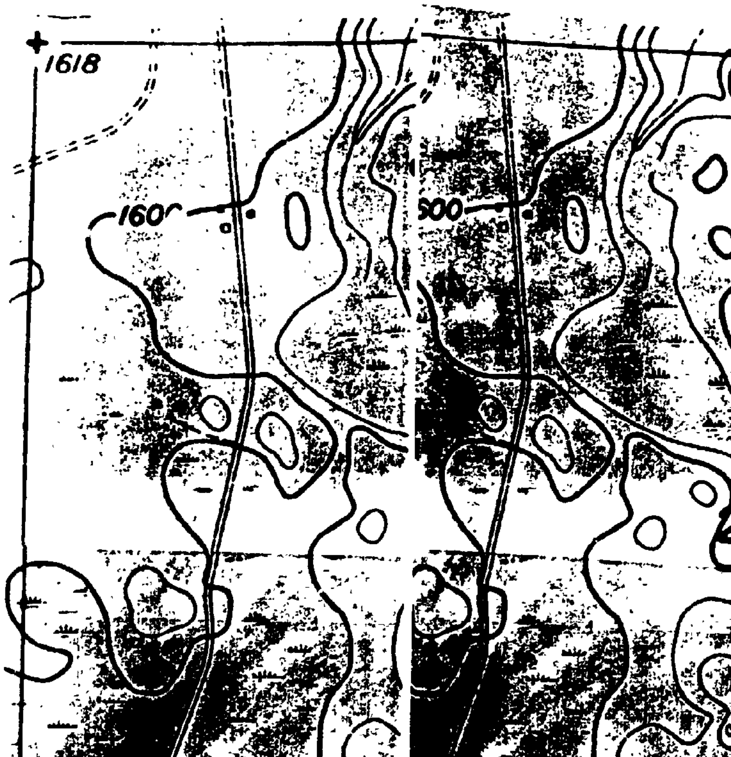
c. gabbro sills and dikes

minor prospect

Projection to surface of go Projection to surface of gold

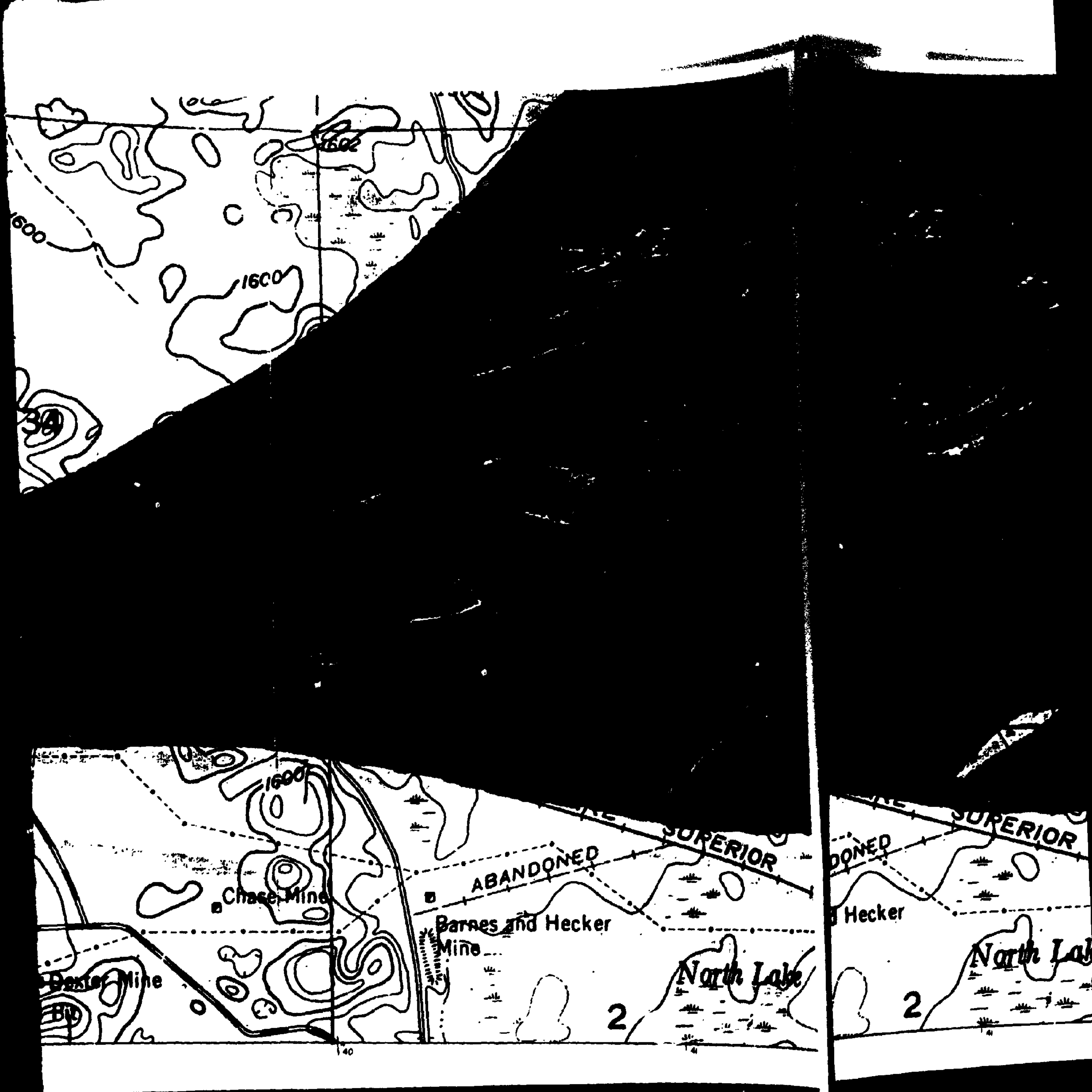
Magnetic low within serpe Magnetic low within serpent

1 numbered locatior in Chapter 3.7.5 numbered location in Chapter 3.7.5

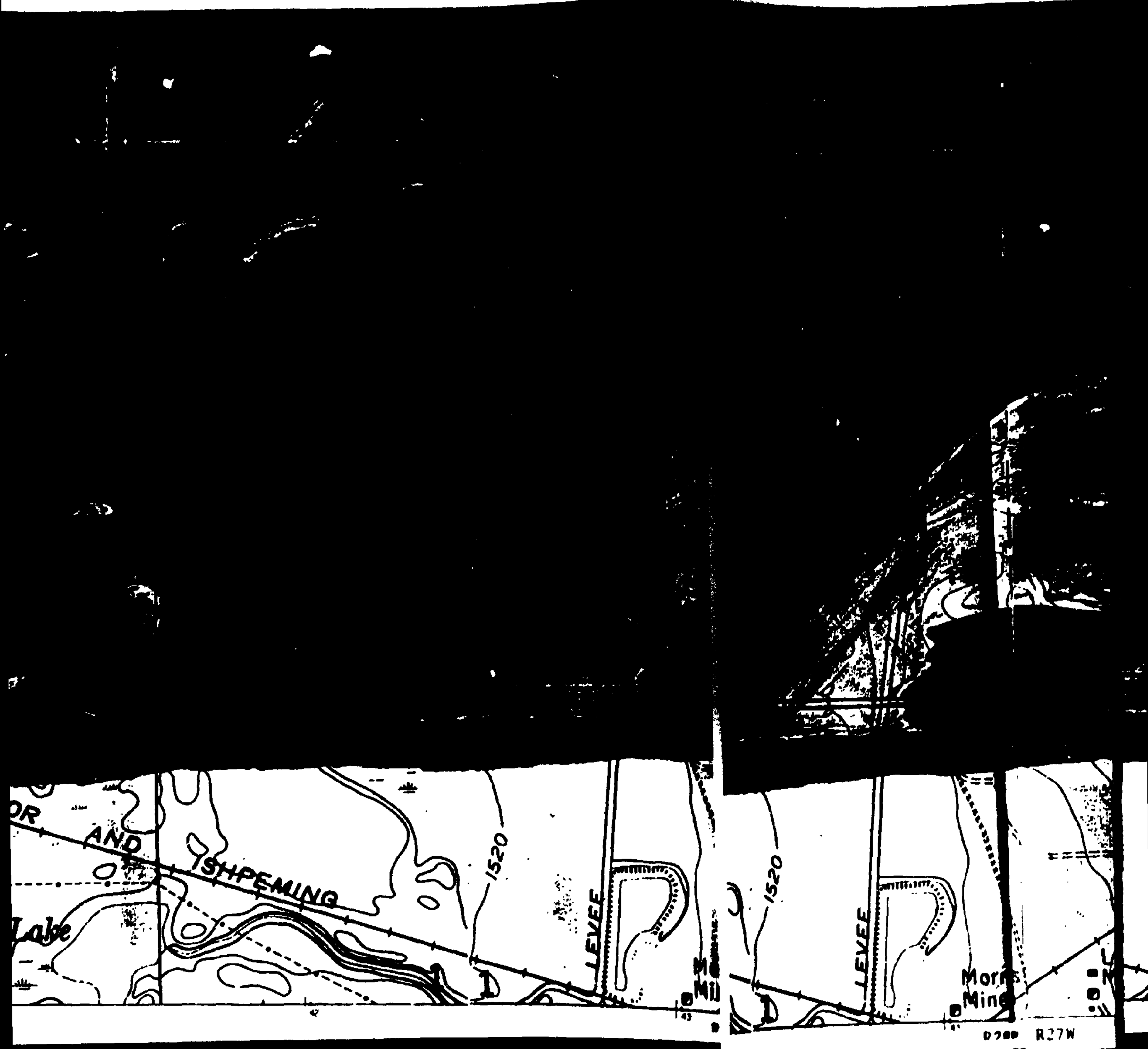


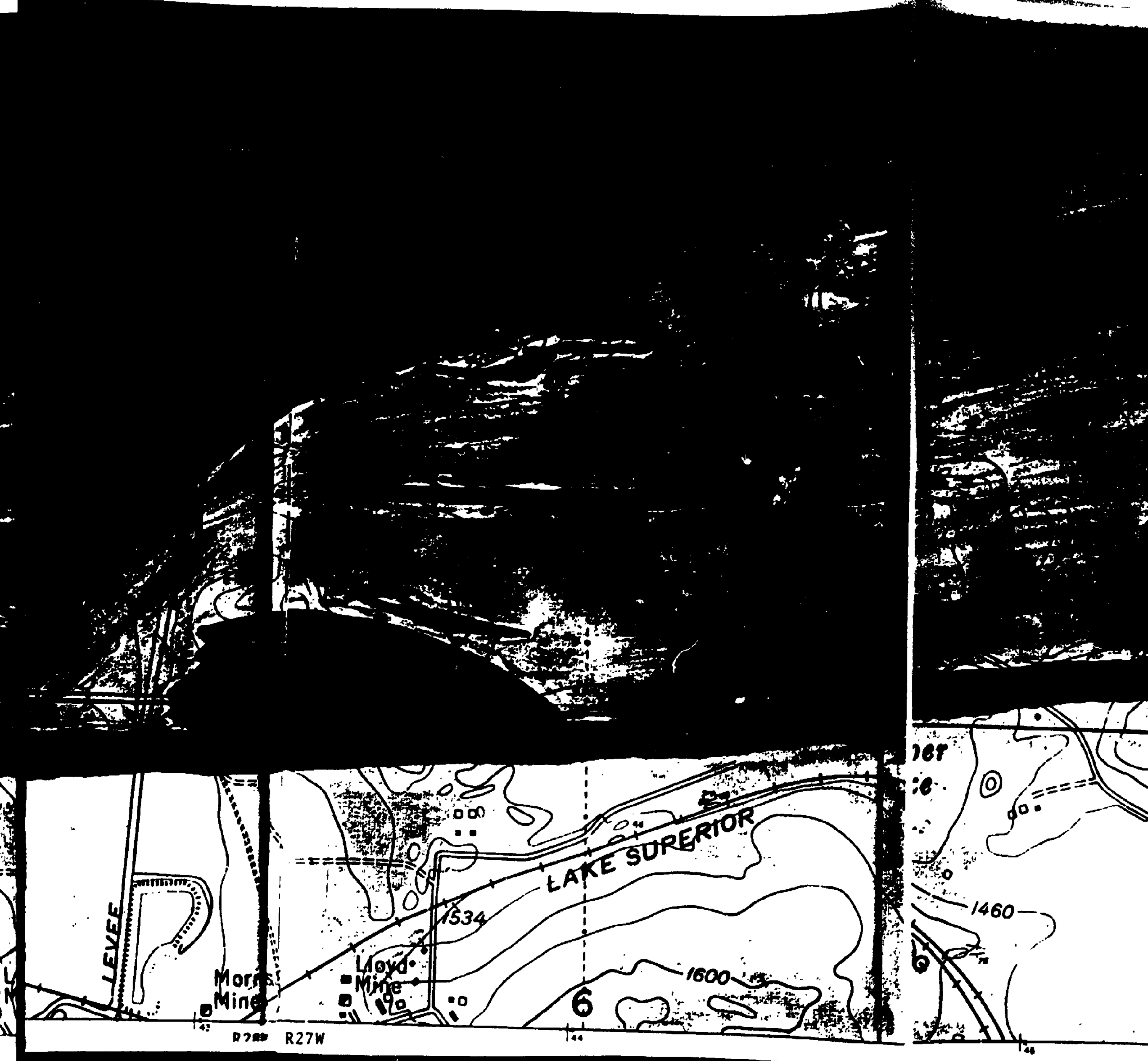

gold ore zone, or significant occurrence
rpentinitic peridotite,
aticn referred to
.5
0 ft. 1000
0 m 305
1500
1516
1600
Gingrass Lake
26

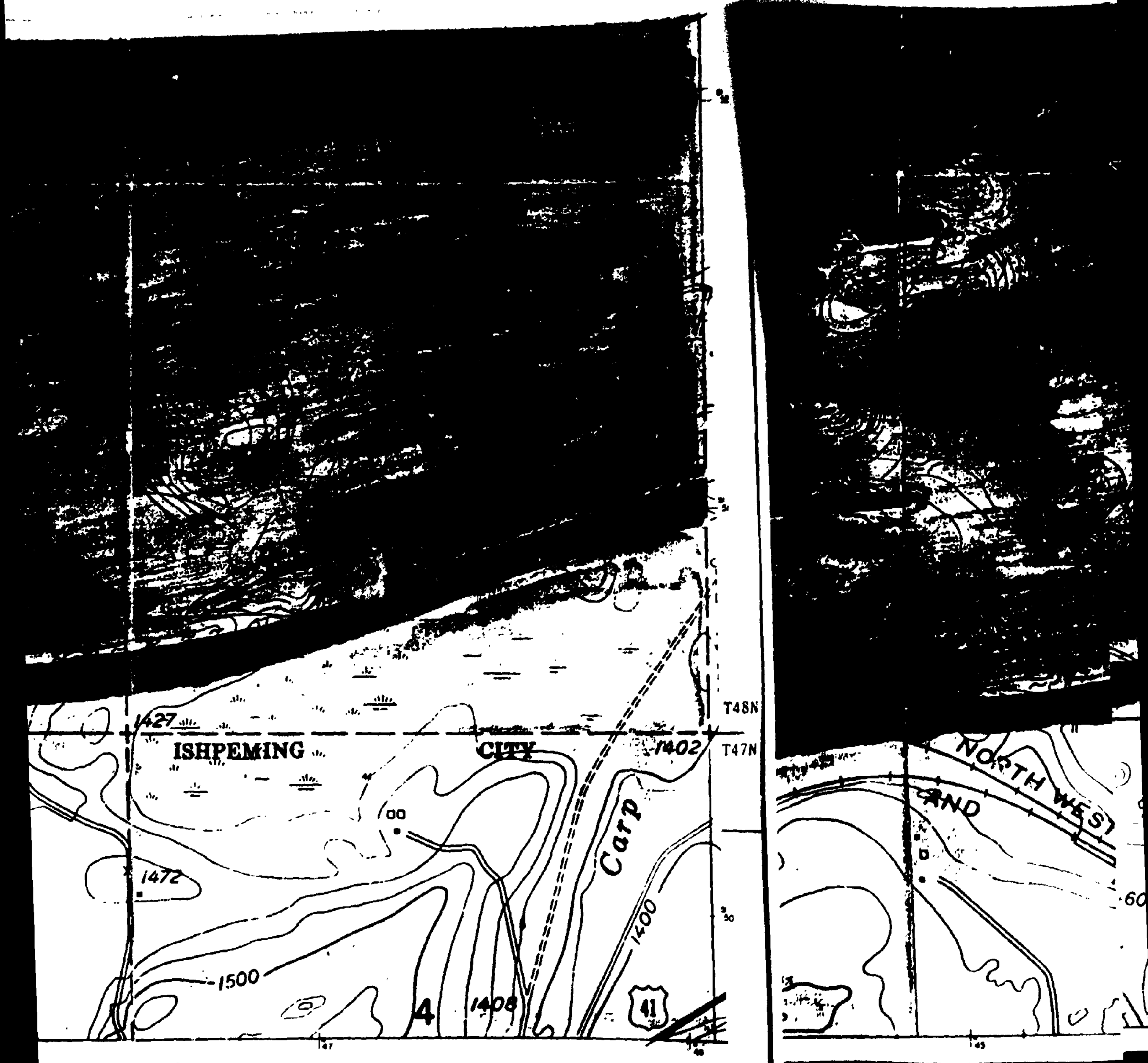

Y



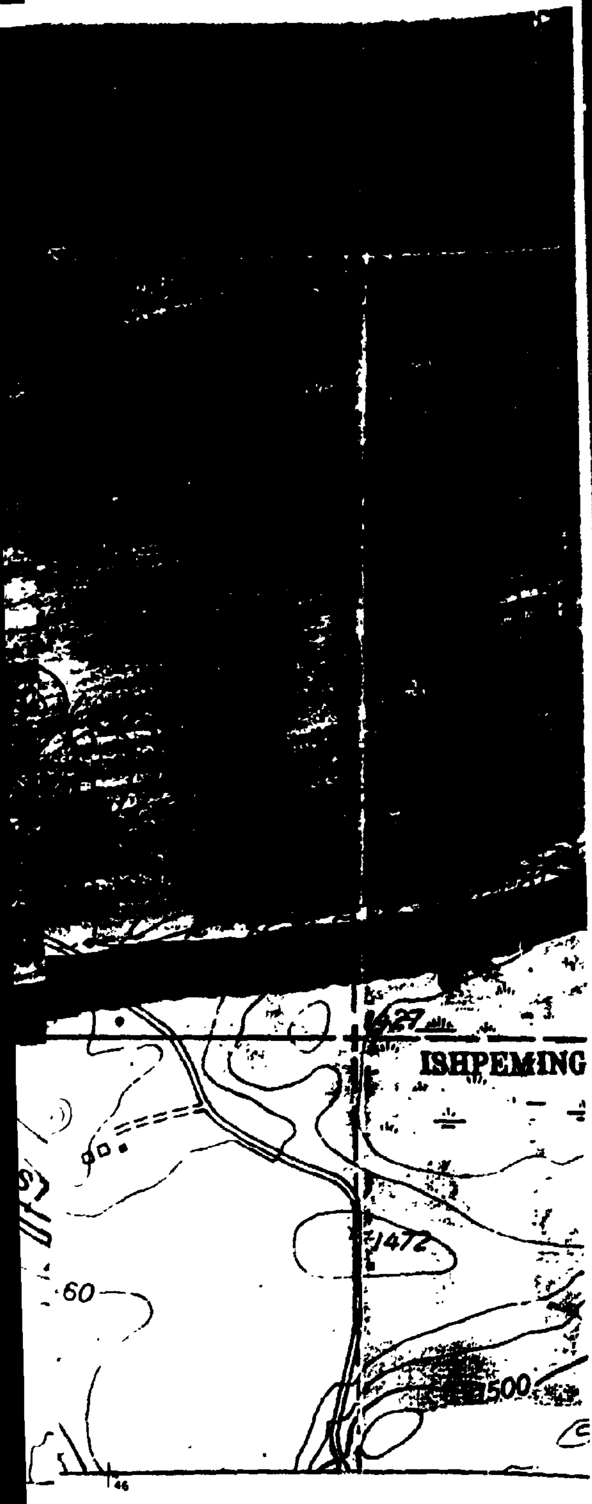
1600
1600
1600
ABANDONED
SUPERIOR
Chase Mine
Barnes and Hecker
Mine
Dexter Mine
North Lake
2
Hecker
North Lak
2


OR
AND
ISHPEMING
Lake
1520
LEVEE
1520
LEVEE
Morris
Mine
R27W


LAKE SUPERIOR
LEVEE
Morris Mine
Lloyd Mine
1534
1600
1460
6
R27W

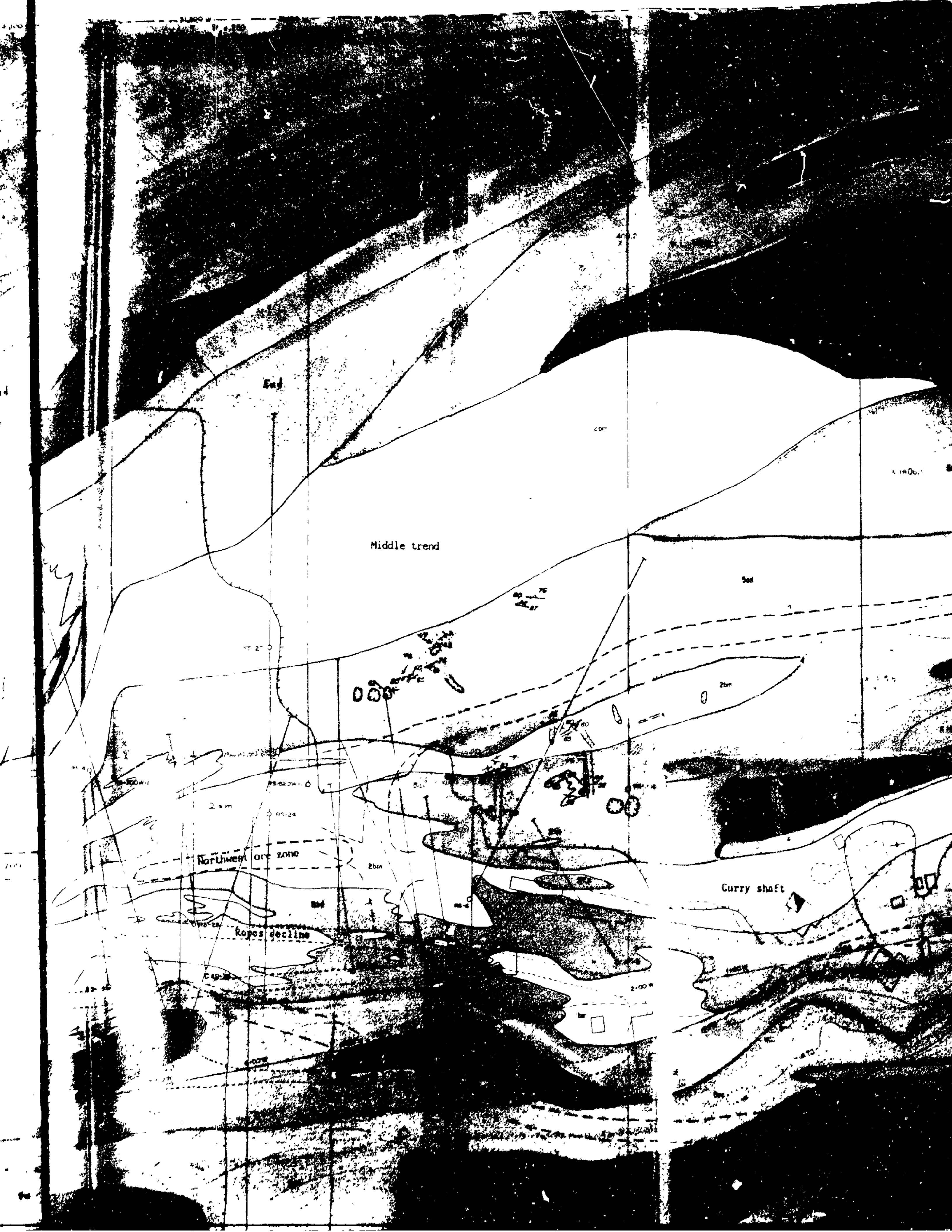


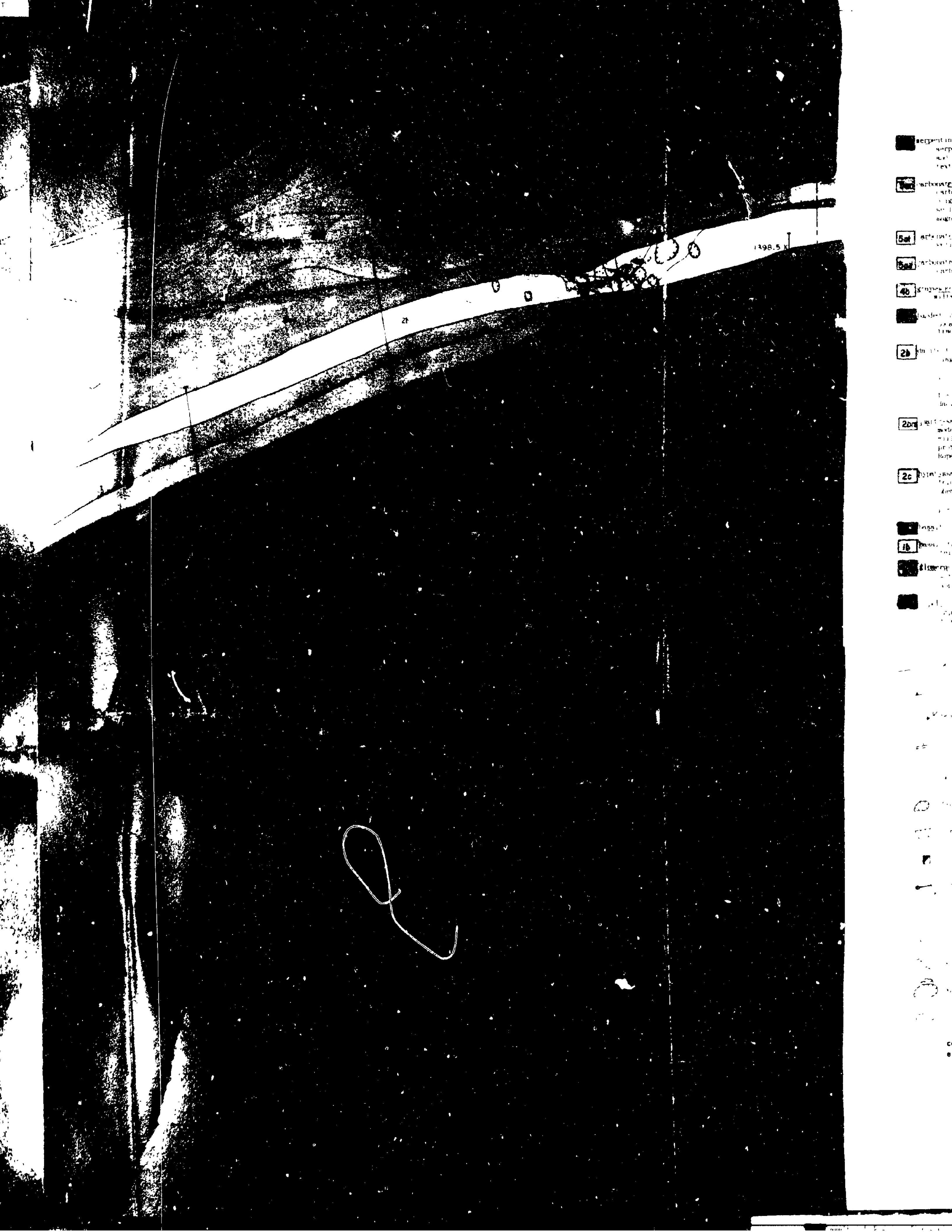
1427
ISHPEMING
CITY
1402
T48N
T47N
Carp
1472
1500
1400
1408
4
41
NORTH WEST
AND


ISHPEMING
1472
60


32,800 W
32,700 W
32,600 W
32,500 W
32,400 W
32,200 W
32,100 W

31,800 W
31,700 W
31,800 W
31,500 W
5ad
2bm
2b

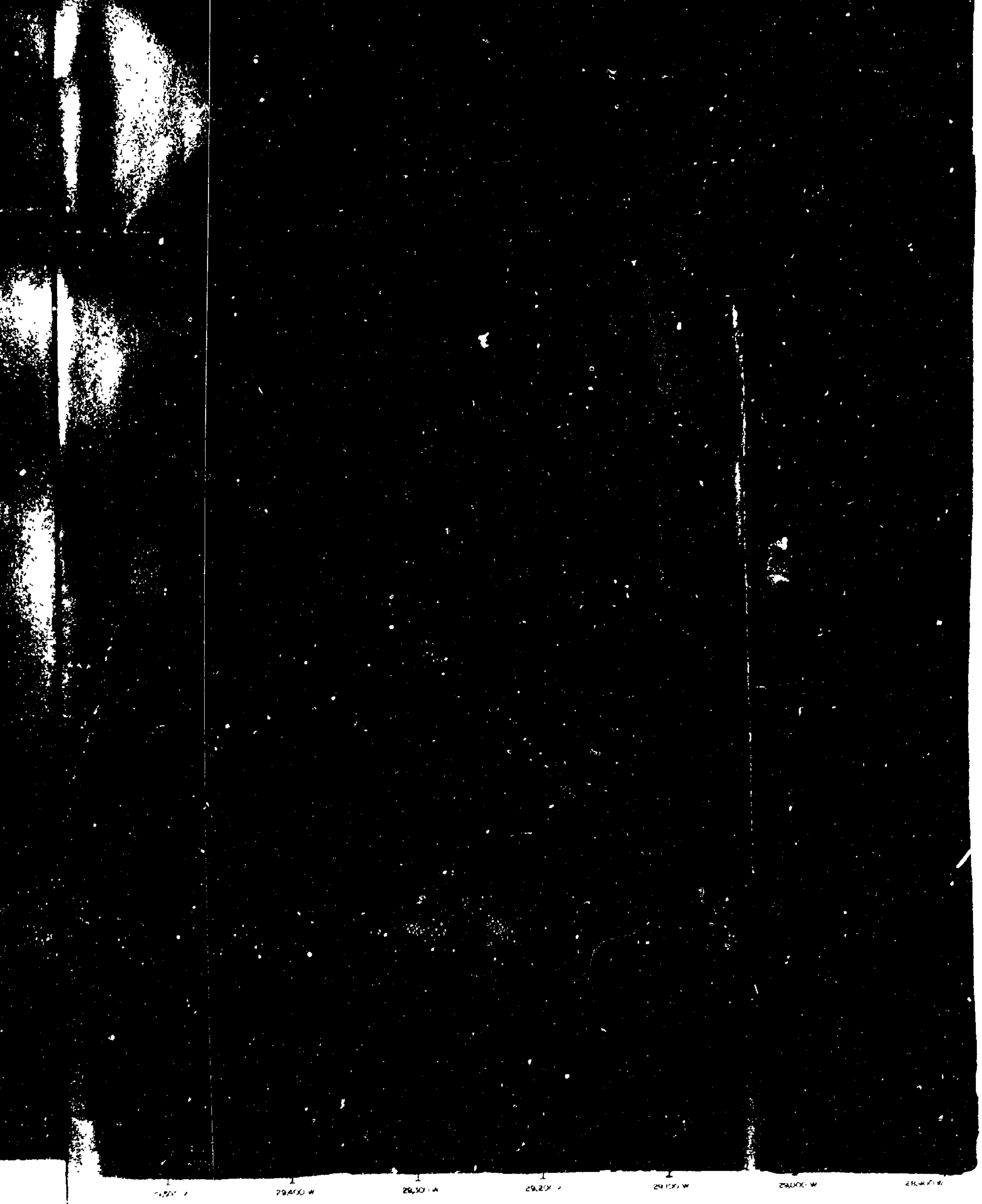

Middle trend
Northwest ore zone
Curry shaft
Ropes decline


1398.5
5at
5ad
4b
2b
2c
1b

Northwest ore zone
Ropes decline
2bm

Northwest ore zone
Royas decline
Curry shaft
2bm
5dl


2bm

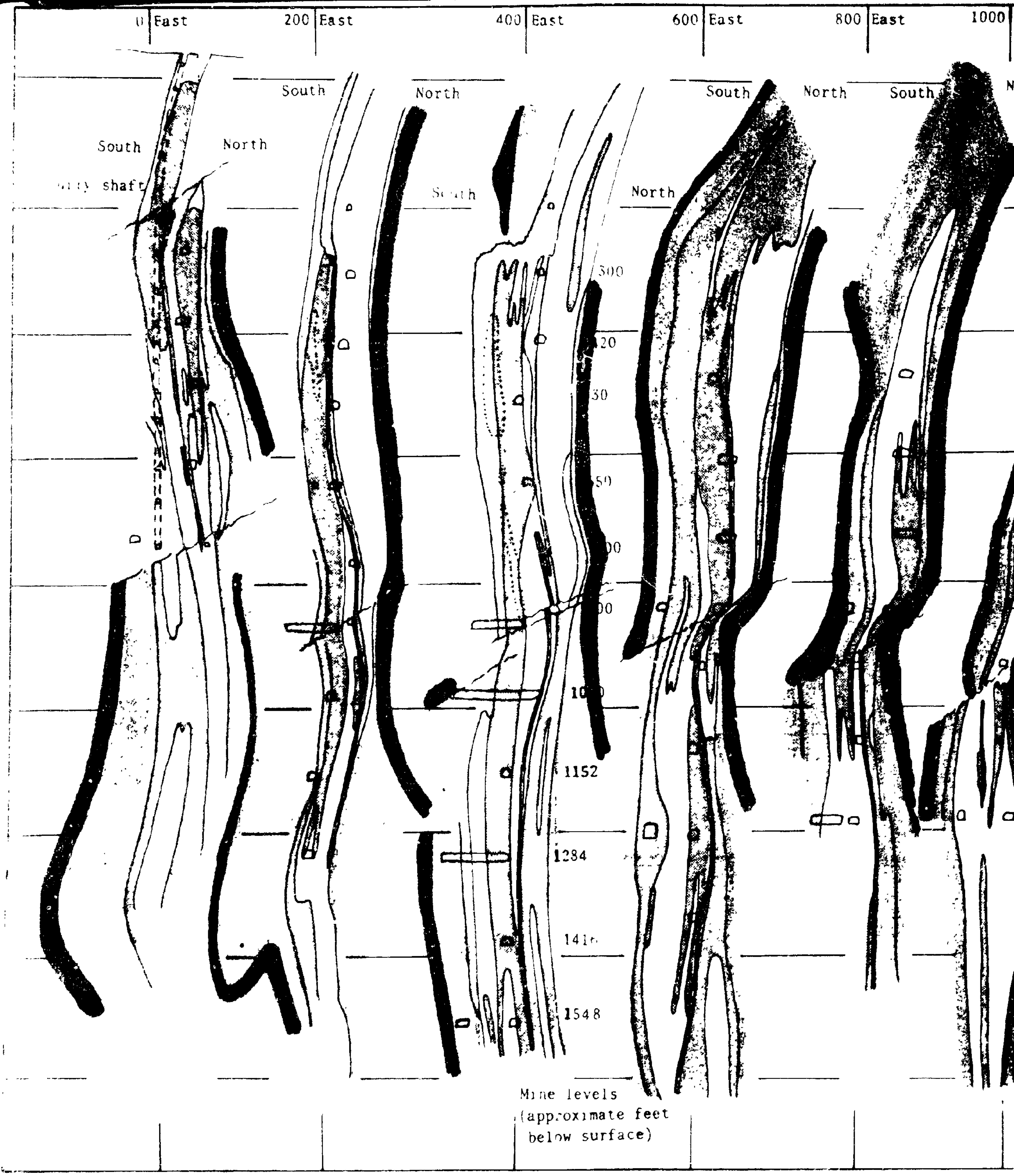


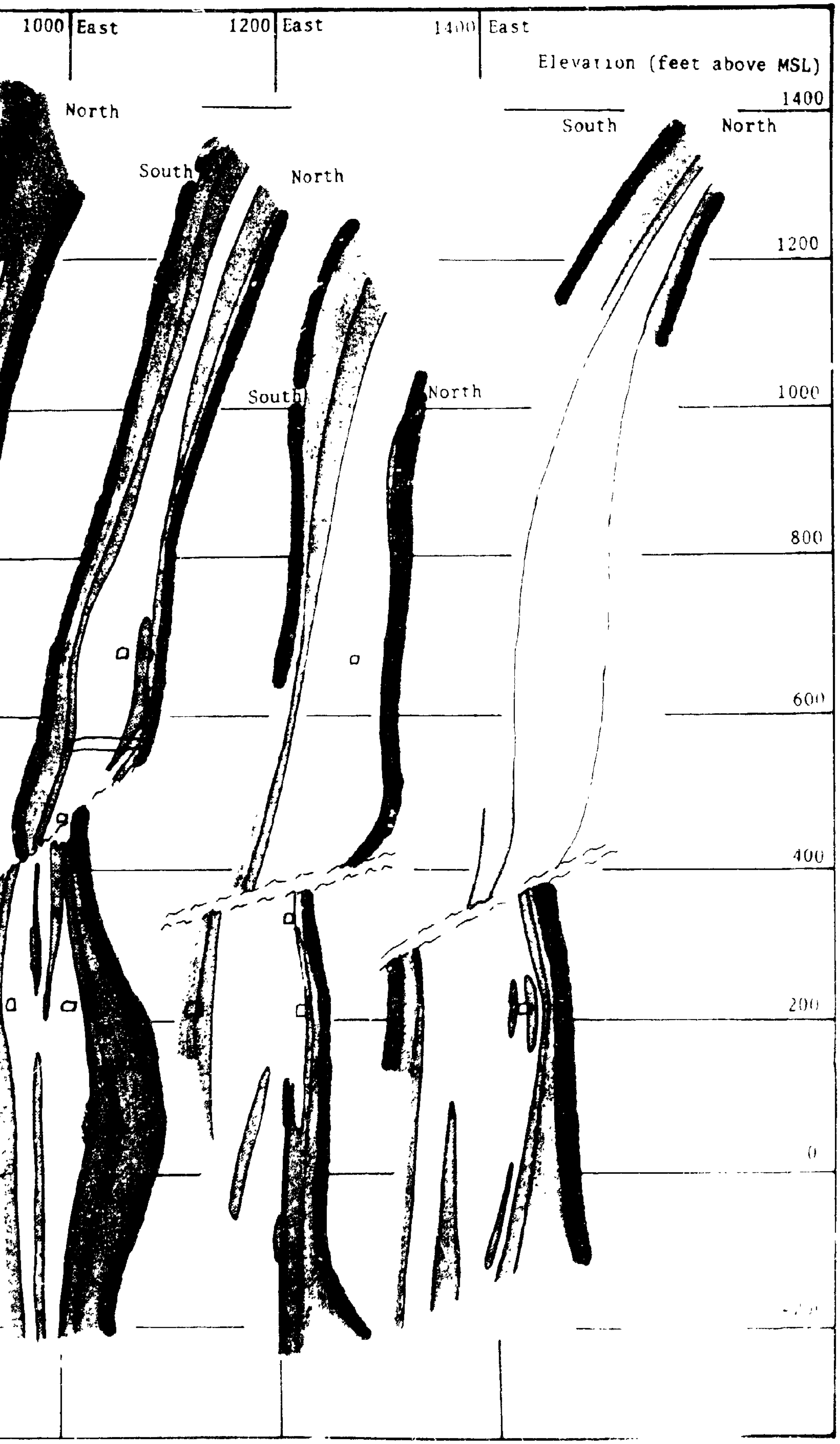
contour interval 2 ft.
elevations is ft. above

0

CALLAH

Plate


0 East
200 East
400 East
600 East
800 East
1000
South
North
South
North
South
North
South
shaft
South
North
300
1152
1284
1548
Mine levels
(approximate feet
below surface)



Map plate 4. Geologic Cros

Ropes Gold D

(redrafted from c

EXPLANATION:

quartz - sericite - chlorite ro

carbonate - quartz - chlorite ro

microcrystalline carbonate - qu

carbonate - talc rock

serpentinitic peridotite

zones of > 2 g/tonne Au

Vertical cross sections in the 350° pl

61 200 horizontal and vertical scales

meters feet

feet 200

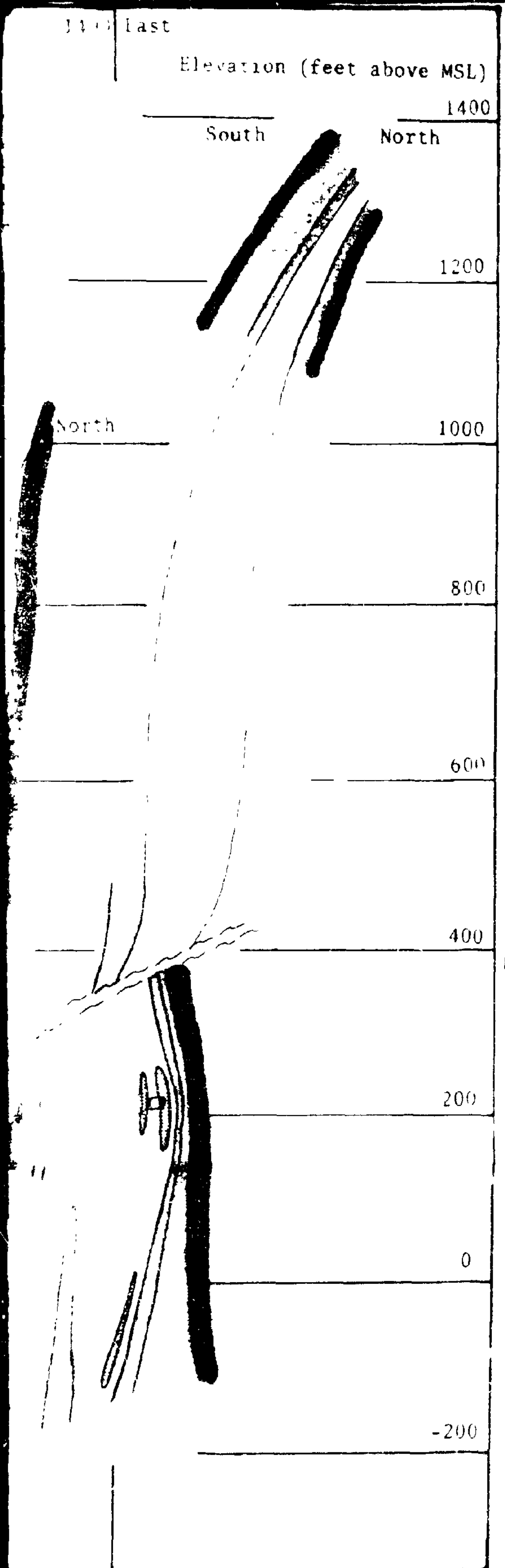
0 meters 61

Geology by

Callahan Mining Corporation (G

A Brozdowski R J Gleason J

Consolidated Mining Co



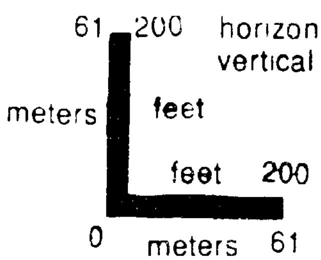
Map plate 4. Geologic Cross Sections through the Ropes Gold Deposit

(redrafted from cross sections drawn by G. W. Sc

EXPLANATION:

- quartz - sericite - chlorite rock
- carbonate - quartz - chlorite rock
- microcrystalline carbonate - quartz rock
- carbonate - talc rock
- serpentinitic peridotite
- zones of > 2 g/tonne Au

Vertical cross sections in the 350° plane, looking 260°



Geology by:

Callahan Mining Corporation (G. W. Scott, D. Bal, J. Bosco, A

A. Brozdowski, R. J. Gleason, J. Strapko) and Calumet and H

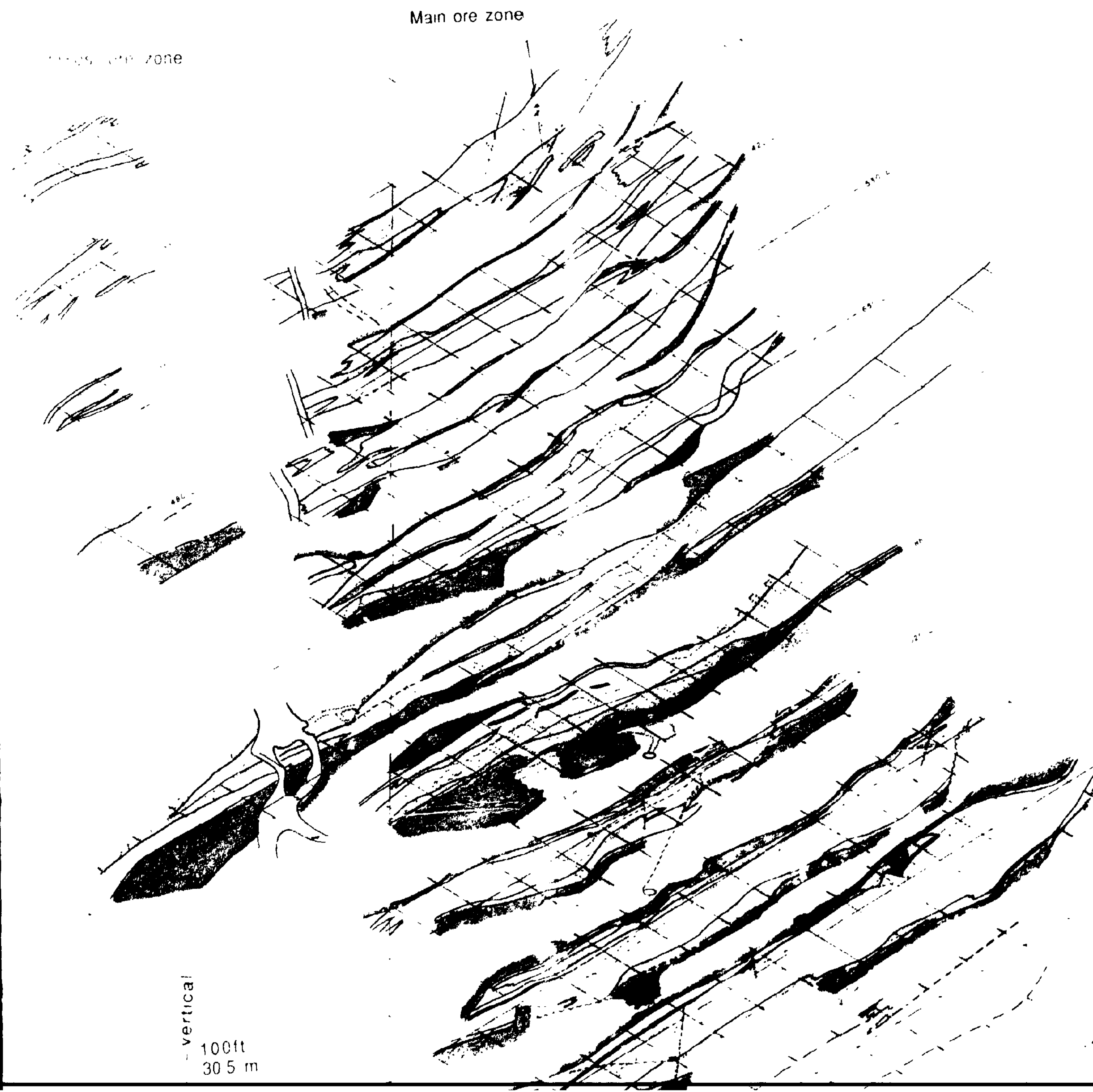
Consolidated Mining Co.

W. Scott)

o, A. S. Carter. R

nd Hecla

Geoloc Callahan Mining Corporation (G. W. Scott, D. Bal, J. Bosc
Carter A Brozdowski, R J. Gleason, J. Strapko) and Calumet and
Cons. a Mining Co
Draw G W Scott
Drafte J Papp



. Bosco, A. S.
et and Hecla

Map Plate 6.

Total Magnetic Field Survey of the North Half of Section 29 T48N R27W

Plotted as (gammas x 100)
Contour interval 500 gammas

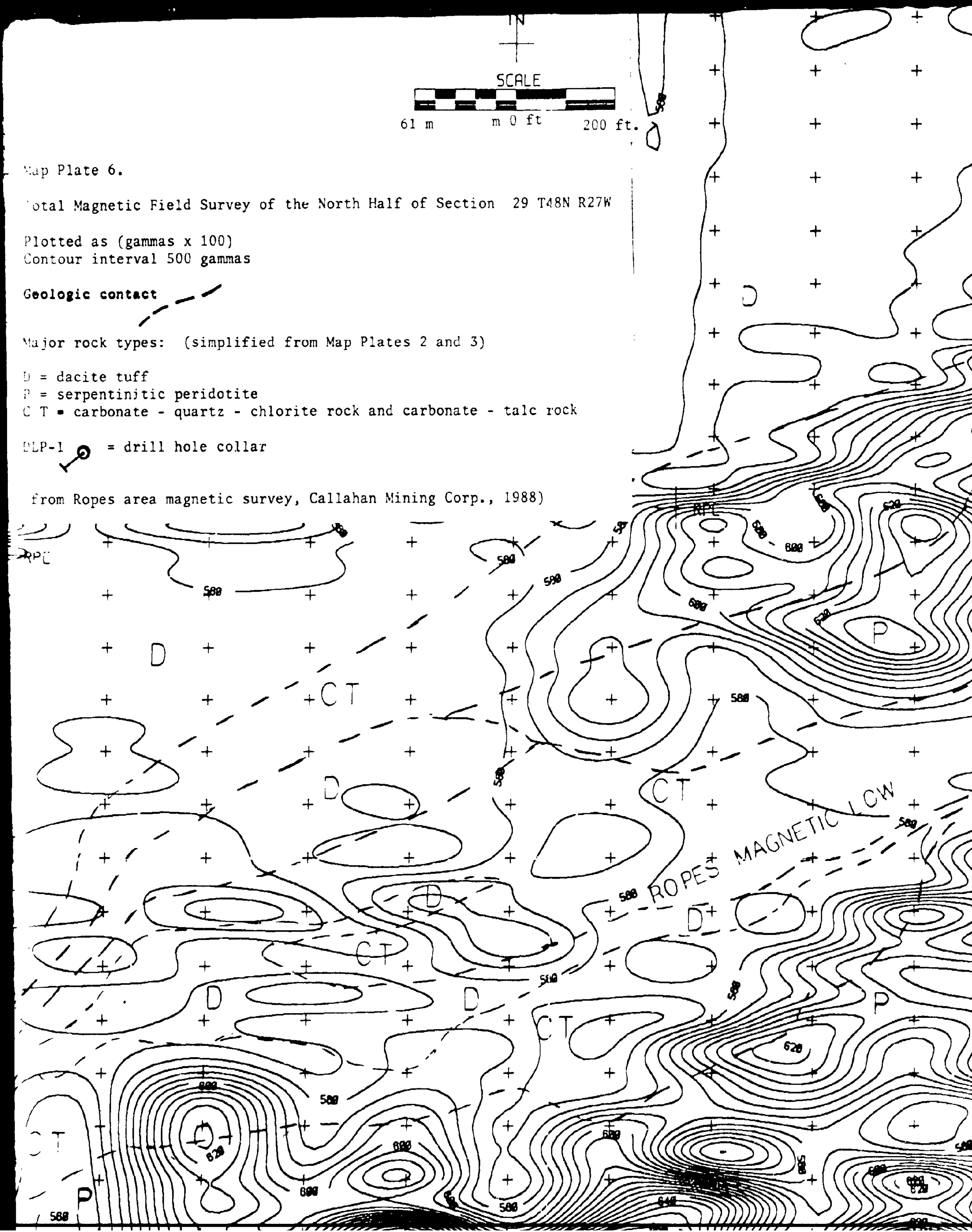
Geologic contact

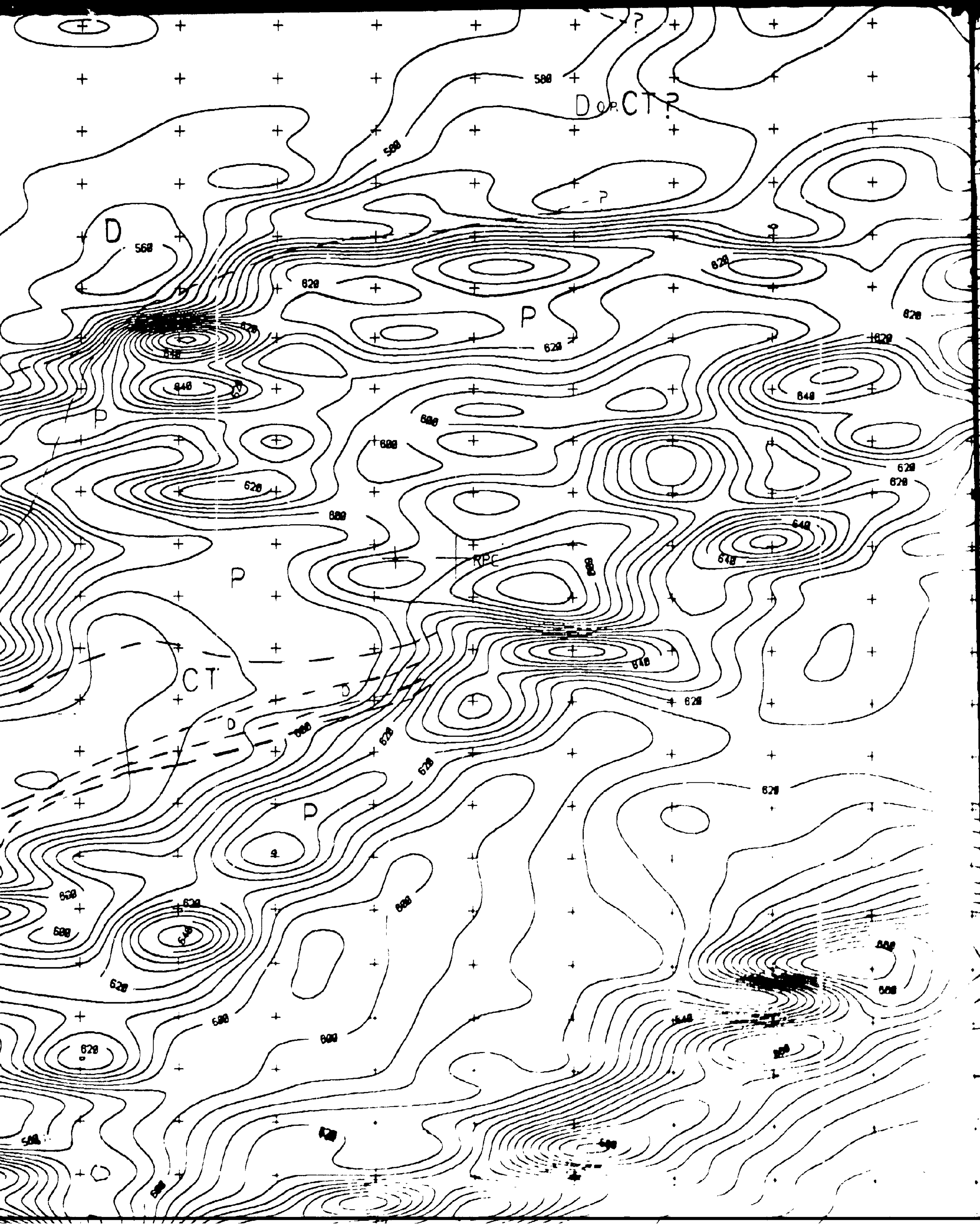
Major rock types: (simplified from Map Plates 2 and 3)

D = dacite tuff
P = serpentinitic peridotite
C T = carbonate - quartz - chlorite rock and carbonate - talc rock

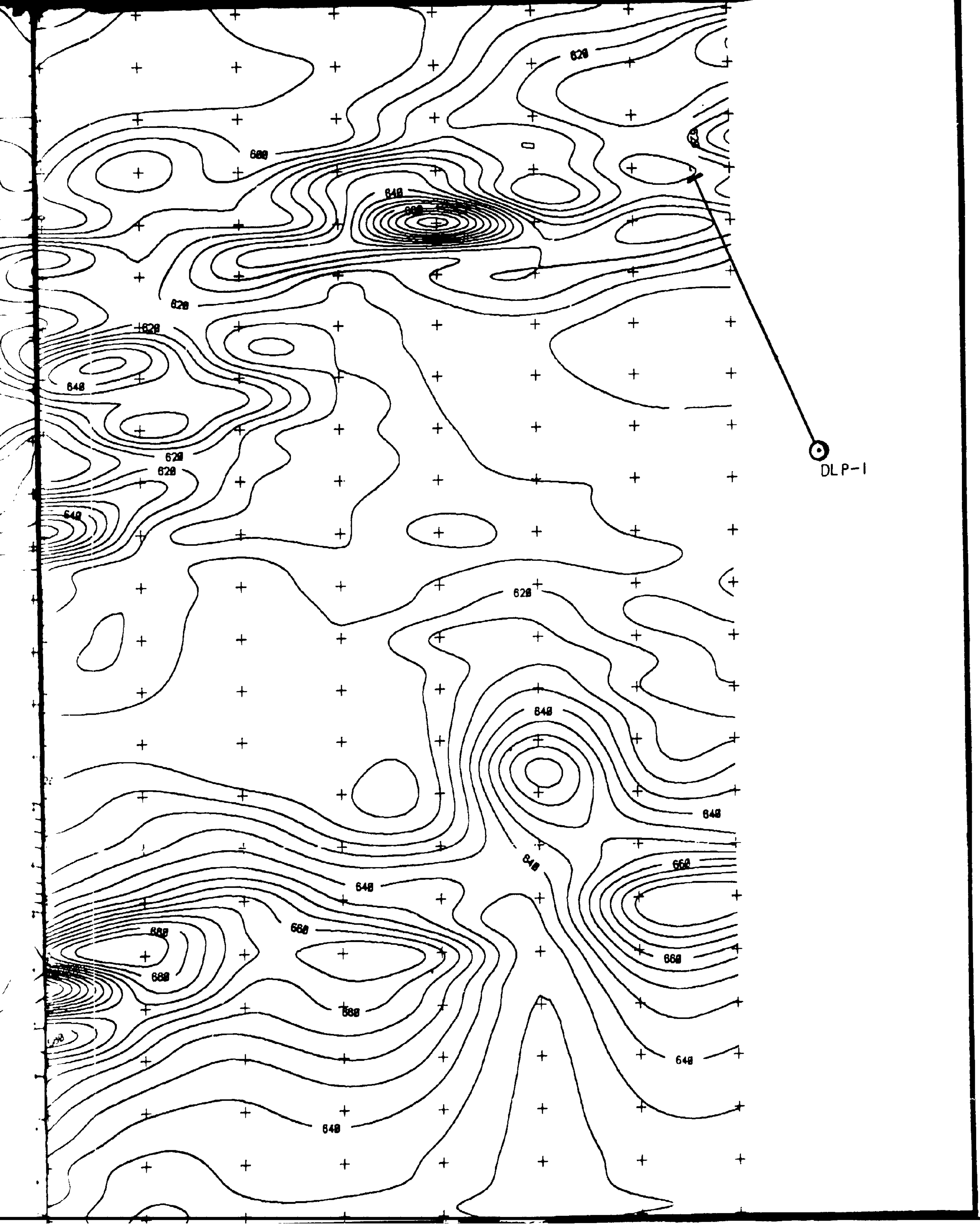
DLP-1 = drill hole collar

(from Ropes area magnetic survey, Callahan Mining Corp., 1988)

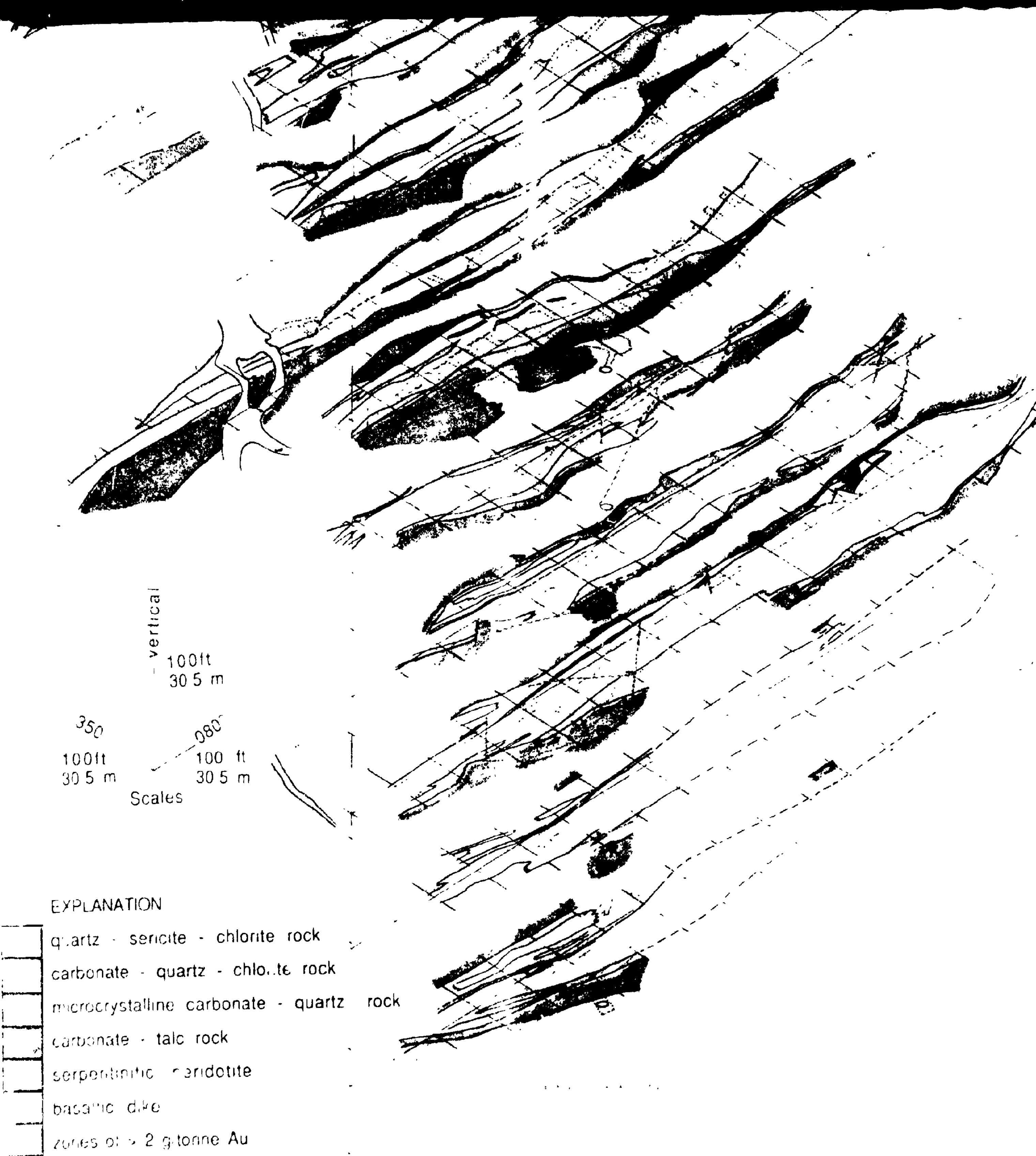




D or CT?
D
P
P
CT
P
RPC



620
600
640
660
620
620
640
620
620
640
620
640
640
660
640
660
680
660
680
640
660
640
DLP-1



Map plate 5. Isometric Diagram of the Ropes Gold De

ld Deposit